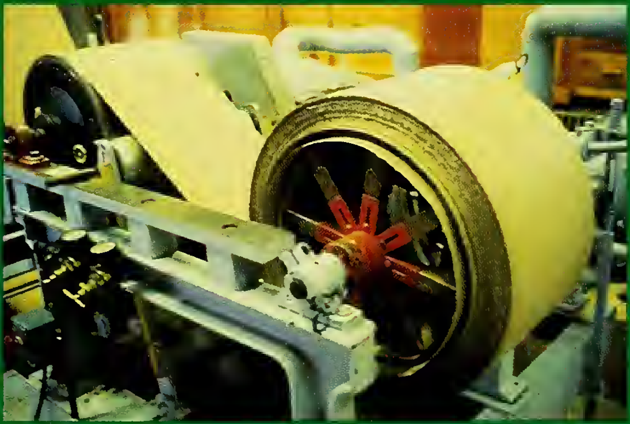
TECHNOLOGY OPPORTUNITIES



United States Department of Agriculture

Forest Service

Forest Products Research

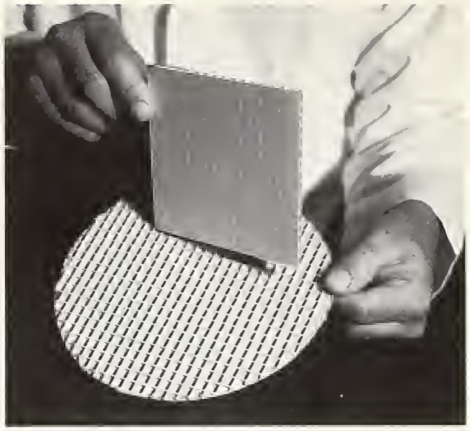
State and Private Forestry

Technology and Innovation

Technology and industrial innovation are central to the economic, environmental, and social well-being of citizens of the United States. Technology and industrial innovation offer an improved standard of living, increased public and private sector productivity, creation of new industries, expanded employment opportunities, improved public services, and enhanced competitiveness of U.S. products in world markets.
—P.L. 96-480, October 21, 1980.

In the past decade, the United States has seen unprecedented changes in the manufacturing and use of forest products. Innovations that extend the Nation's timber resource and promote the substitution of wood for strategically important, nonwood materials have addressed important U.S. socioeconomic needs. Underlying these changes are solid technical data collected through disciplined research efforts in government, university, and industry laboratories. Most applications of these research results have involved the cooperative efforts of researchers, technology users, and transfer agents.

The Federal Technology Transfer (TT) Act of 1986, which supplements the Stevenson-Wydler Act of 1980, expedites the application of technology developed under federal funding. Its



goals are to benefit the U.S. economy and to enhance the competitive position of U.S. manufacturing and service industries.

Through the TT Act of 1986, Forest Service Regional Foresters and Directors have new authority to initiate cooperative research and development agreements with industrial firms and others. These agreements protect confidential business information and clarify ownership of intellectual property (e.g., patents) arising from the partnership. In addition, royalty income from a federally owned patent can now be shared with a federal employee-inventor and his or her agency before the remainder is added to the U.S. Treasury. The TT Act of 1986 provides almost unlimited opportunities for facilitating the transfer of existing knowledge and new technology.

The objective of the USDA Forest Service Technology Transfer Program is to apply appropriate knowledge and technology to the management and utilization of the Nation's forests and associated rangelands. It also facilitates the transfer of Forest Service research and technology to State and local governments and to the private sector.

To strengthen our technology transfer efforts, we offer this series of one-page Techlines based on the results of Forest Service wood utilization research. These summaries describe an array of concepts, emerging technologies, recent developments, and state-of-the-art knowledge with potential for commercial application. The topics were selected for their potential for application and their economic significance and feasibility. A technical contact is specified for each subject to facilitate linkage with federal and state foresters, utilization and marketing specialists, extension specialists, educators, forest product industry representatives, and other users.

These findings come from the Forest Service forest products utilization research program. The program focuses on expanding the range of timber products, developing more efficient processing methods, and deriving safe and durable wood-based materials. About 70 percent of this research effort resides at the Forest Products Laboratory in Madison, Wisconsin. Experiment Stations in the Intermountain, North Central, Northeast, Pacific Northwest, Pacific Southwest, Rocky Mountain, South, and Southeast regions conduct additional studies.

During its long history, Forest Service utilization research has increased our basic knowledge of the characteristics and properties of wood, wood fiber products, engineered wood products, and paper. Accelerated work during World Wars I and II increased our knowledge of sawing, milling, lumber drying, gluing, panel products, and new and improved pulping processes—all major components of today's wood products industry. Research on improved protection methods has extended the service life of wood already in use. Recent advances in microbial research and biotechnology show promise in industrial applications, such as biopulping and soil/wastewater bioremediation technology. Continued research in all these areas will improve the productivity of our forest resources and keep the United States competitive in world markets.

For further information, contact:

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Technology Opportunities
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Forest Products Laboratory Publications Lists

The Forest Products Laboratory (FPL) conducts research on all aspects of conversion and use of the timber resource. This work has resulted in many technical reports, scientific articles, and USDA handbooks. To help the users of FPL research locate material pertinent to their interests, reports have been grouped into a series of FPL Publications Lists. Each list covers a major area of wood utilization research or several topics of interest to a particular audience. The 16 available lists and the subjects they cover are:

Biodeterioration and Protection of Wood
Stain, decay, fungi, durability, marine environments, termite control, preservatives and finishes, corrosion

Drying of Wood
Physical properties related to drying: Permeability, diffusion, and drying rate; shrinkage and swelling; moisture content; stresses. Lumber drying methods: Air drying, kiln drying, solar drying, special drying methods. Moisture content and temperature control during fabrication and use.

Energy from Wood
Liquid fuels, fuelwood, energy and chemicals from wood

Exterior Wood Finishing
Finishing and durability, finishing research

Fiber and Particle Products, Plywood, and Veneer
Wood and nonwood composites, particleboard, flakeboard, panel products, plywood, laminated veneer lumber, veneer peeling and processing

Fire Safety
Performance of wood in fire, fire-retardant treatments, fire growth modeling

Packaging
Corrugated fiberboard containers, cushioning, pallets, fasteners

Sawing and Related Processes
Sawing; cutting and slicing; grades, specifications and standards

Structure and Identification of Wood
Wood quality, wood properties, techniques, microstructure of wood, general wood structure

Timber Requirements and Economics
Resource supplies and demands, processes, computer programs and methods

Wood Bonding Systems
Types of adhesives and characteristics, gluing of wood, gluing of non-wood materials, durability of adhesives, laminated wood and glued assemblies

Wood Chemistry
Analysis of wood and wood products. Chemical properties: Cellulose and hemicellulose, extractives. Conversion of wood: Biochemical, chemical; modified woods

Wood Fiber
Pulp and paper, biotechnology, paper testing, bleaching, recycling, interfiber bonding

Architects, Engineers, Builders and Lumber Retailers
Buildings and structures, components, materials, joints and fastenings, moisture control and insulation, acoustics

Furniture Manufacturers and Woodworkers
Physical and mechanical properties of wood, glues and gluing; wood preservation; drying and seasoning; finishing; sawing

Teachers of Industrial Arts and Vocational Education
Building materials, drying, economics, finishing and protection, fire-retardant treatments, glues and gluing, structures, wood properties

Each entry in a Publications List provides the title, author, and date of the paper, and the source of the publication. Not all publications are available from the Forest Products Laboratory. Some are handled through public sales outlets such as the U.S. Government Printing Office or National Technical Information Service; others are handled by private publishers. In all cases, complete addresses for sources are given. Costs may be involved and are provided when known.

The lists can assist researchers, industry, regulatory agencies, legislative bodies, landowners, educators, other government agencies and the general public in locating information about an array of forest products.

Single copies of any of the above Publications Lists are available from:

Information
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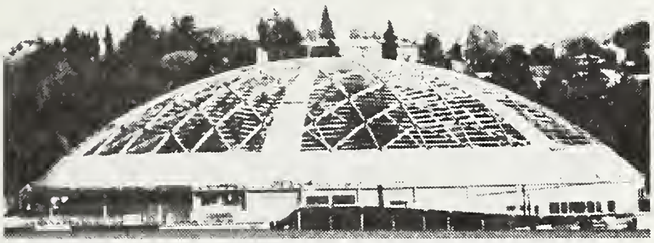
'ECHLINE

Engineering Properties and Design Criteria

Wood Handbook: Wood as an Engineering Material

In 1910, the Forest Products Laboratory (FPL) at Madison, Wisconsin, was established as the first institution in the world to conduct general research on wood and its use. The vast accumulation of information that has resulted in eight decades of research provides the basis for the U.S. Department of Agriculture's most recently revised *Wood Handbook*. This publication covers the FPL's engineering and allied investigations of wood and wood products, along with knowledge of everyday construction practices and problems.



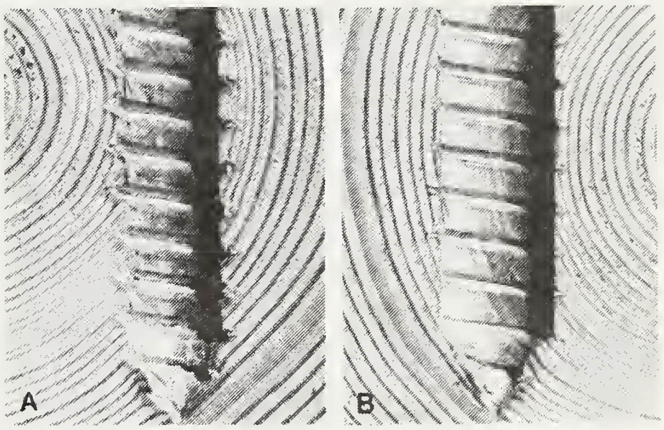
At 530 feet in diameter and 157 feet tall, this dome at Tacoma, Washington, is both the largest wood dome and the longest clear-span wood roof structure in the world. (Courtesy of Western Wood Structures, Inc.)

The purpose of the *Wood Handbook* is to serve as an aid to more efficient use of wood as a construction material. The handbook is designed to give engineers, architects, and builders an authoritative source of information on the physical and mechanical properties of wood, wood composites and fastenings, and how these properties are affected by end-use conditions. In the past, practical knowledge of wood has resulted in strong and beautiful structures, even though exact engineering data were not always available. Continuing research and evaluation techniques are improving our knowledge and promise to permit wider and more efficient utilization of wood and to encourage even more advanced industrial, structural, and decorative uses.

Individual chapters of the *Wood Handbook* describe the wood itself, wood-based products, and the modern principles of how wood is dried, fastened, finished, and preserved from degradation. Each chapter concludes with a list of selected references for additional information.

A glossary of terms is also included. The common and botanical names for different species mentioned in this volume conform to the official nomenclature of the Forest Service. Information on selected foreign species is included to reflect the increasing importance of imported species. English and metric systems of measurement are used for selected sections throughout the handbook. A conversion table is given inside the back cover.

The *Wood Handbook* was first issued in 1935 as an unnumbered FPL publication. The handbook was slightly revised in 1939. It was further revised in 1955, 1974, and 1987. These last three editions were designated Agriculture Handbook No. 72. The enhancements were necessary to reflect the substantial research accomplishments since the earlier editions and recent changes in technology.



The Wood Handbook contains detailed information to assist engineers, architects, and builders. Illustrated is the importance of correctly sized lead holes. A—clean-cut, deep penetration of thread made by lag screw turned into properly sized lead hole and B—rough, shallow penetration of thread made by lag screw turned into oversized lead hole.

To order copies, contact:
Superintendent of Documents
U.S. Government Printing Office
710 N. Capitol Street
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Requests should include complete title and stock number as follows: Agriculture Handbook No. 72, Wood Handbook; Stock No. 001-000-044-56-7. Current price $27.00 (subject to change without notice).

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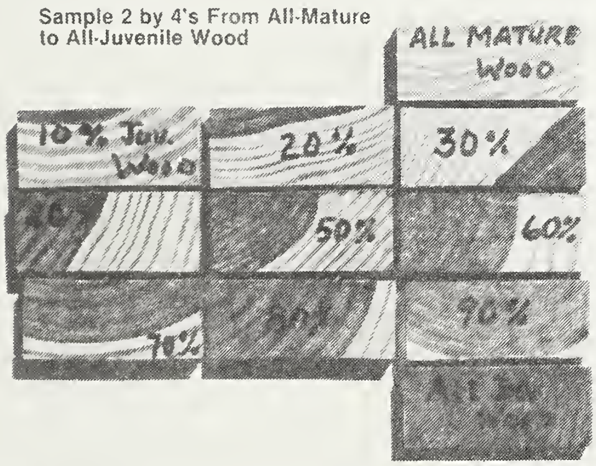
'ECHLINE
Engineering Properties and Design Criteria

Properties of Juvenile Wood

Juvenile wood is the wood a tree lays down in its first 5 to 20 years of growth, which has different characteristics than normal or mature wood. In conifers, it has lower specific gravity, shorter tracheids, larger fibril angle, lower transverse shrinkage, higher longitudinal shrinkage, lower strength, lower percentage of latewood, more compression wood, thinner cell walls, larger lumen diameters, and lower cellulose but higher lignin content.

Within the juvenile wood core, these properties are not uniform from the pith outward. Rather, the wood in the first few rings from the pith has the most extreme differences (for example, lowest specific gravity), but the characteristics of later cells gradually improve during a "transition" period until normal or mature wood is produced. Tree species vary in how many annual rings of juvenile wood are created before the mature wood appears.



The makeup of a given board can range from no juvenile wood to entirely juvenile wood, depending on where the board was cut from the log. The presence of juvenile wood affects the board's properties.

All trees have juvenile wood, but it had little significance when the timber supply was primarily old-growth trees grown in natural forest conditions. On such trees, the juvenile wood core was small because early growth was suppressed by competition from surrounding trees. In addition, the percentage of juvenile wood in the total volume was small because trees grew to a very large diameter before they were harvested. Now, improved trees grown on intensively managed plantations reach sawtimber size and are harvested at a young age. Because diameter growth is generally fastest during the years juvenile wood is produced, the juvenile wood core may be a very significant part of the harvest.

The paper industry has adapted to the increasing proportion of juvenile wood in their raw material by blending it with mature wood of other trees or species and/or by improved pulping technology. Some properties of paper are actually improved with juvenile wood.

For most solid wood products, however, juvenile wood is inferior to mature wood. The lower strength and stiffness and the higher shrinkage in the lengthwise direction are the principal problems. The higher shrinkage can result in excessive warp in lumber, especially when a piece has juvenile wood on one side and normal wood on the other. Research is demonstrating that warp can be controlled within acceptable limits by sawing and drying practices such as the saw, dry, and rip process. (A Techline on the Saw–Dry–Rip Process is available.)

Juvenile wood's effect on the ultimate strength of dimension lumber continues to be of concern. Recent research shows that dimension lumber cut from the juvenile wood core may have only 50 to 70 percent of the strength and stiffness of lumber cut from mature wood, depending upon the grade and species. The National In-Grade Testing Program measured the actual strength and stiffness of lumber currently on the market. (A Techline on the In-Grade Testing Program is available.) These results are helping lumber standards groups modify design stresses to account for the changing timber resource. However, as the industry harvests more young, fast-growth, plantation-grown trees with high proportions of juvenile wood, allowable design stresses may need to be modified further.

Current research is focusing on evaluating the strength and stiffness of lumber cut from fast-growth loblolly pine plantations. The influence of varying amounts of juvenile wood on the dimensional stability and mechanical properties of laminated veneer lumber processed from fast-growth Douglas-fir and southern pine lumber is also being evaluated.

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Reference

Bendtsen, B. Alan. 1987. Quality impacts of the changing timber resource on solid wood products. In: Robertson, Doris, coord. Managing and marketing the changing timber resource: Proceedings 47349; 1986 March 18–20; Fort Worth, TX. Madison, WI: Forest Products Research Society: 44–57.

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ECHLINE
Biodeterioration and Protection

Protecting Wood from Humidity

Whether indoors or outdoors, wood is always affected by moisture. Wood swells when it gets wet and shrinks as it dries, whether the moisure is liquid water like rain or dew or just high humidity. But, wood coated with the right finishes will be less affected than wood left completely unfinished.

Tests conducted at the Forest Products Laboratory (FPL) on the moisture-excluding effectiveness of finishes on wood surfaces show that no coating applied on wood entirely prevents it from picking up moisture in high humidity or giving off moisture in low humidity. Researchers did find that the moisture-excluding effectiveness of wood finishes varied greatly. Some were very good to excellent, some were poor, and many were in-between. Best effectiveness was found when three coats of finish were applied to the wood surface.

Moisture-excluding effectiveness (MEE) of wood finishes (3 coats after 14 days at 90% relative humidity)

Finish	MEE
Melted paraffin wax (one-coat dipped)	95
Two-component epoxy/polyamide gloss paint	87
Aluminum-pigmented polyurethane gloss varnish	84
Soya-tung alkyd satin enamel	80
Pigmented flat shellac	73
Two-component polyurethane wood sealer	63
Orange or white shellac	46
Phenolic/tung floor sealer	35
Paste wax	1
Linseed oil	0

Several factors determine how effective a finish will be in controlling moisture. One is film thickness. Generally, the more coats applied, the slower the moisture changes and the greater the protection. A second factor is the type of finish used. Pigmented coatings such as oil-based paints are usually more effective in retarding moisture changes than clear coatings such as varnishes and shellacs. A third factor is time. Even good coatings lose their effectiveness over time. The longer the exposure, the lower the effectiveness. Finally, finishes will protect wood from moisture only when applied evenly to all wood surfaces. Unequal coatings on the surfaces of a wood piece may cause unequal shrinkage and lead to warp.

Controlling moisture is very important in using wood indoors as well as outdoors. The information developed on moisture exclusion should be helpful in determining which finish should be used for a particular need. This information is particularly valuable to furniture finishers or to anyone wishing to protect wood from high or low humidity.

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References

Feist, W.C.; Little, J.K.; Wennesheimer, J.M. 1985. The moisture-excluding effectiveness of finishes on wood surfaces. Res. Pap. FPL-462. Madison, WI: USDA Forest Service, Forest Products Laboratory.

Feist, W.C.; Little, J.K.; Wennesheimer, J.M. 1985. The moisture-excluding effectiveness of finishes on wood surfaces—support data. Madison, WI: USDA Forest Service, Forest Products Laboratory. *(Available from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161)*

Feist, W.C.; Peterson, G. 1987. Protecting wood from humidity. Fine Woodworking 64(May/June):59–61.

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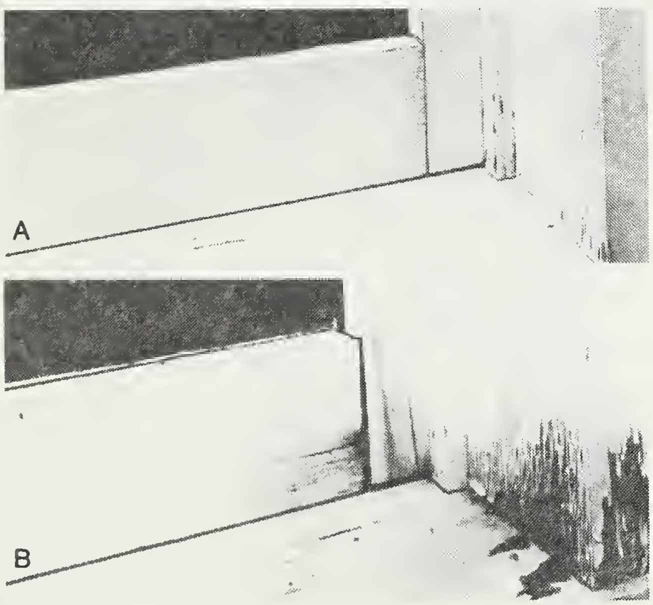
ECHLINE
Biodeterioration and Protection

Finishing Wood Exteriors in the South

Wood's ability to take and hold a variety of finishes makes it a very versatile material. It is widely used outdoors for siding, decking, fencing, and other architectural purposes. Finishes used include clear ones that reveal and accentuate the natural beauty of wood, stains that impart a rustic appearance, and paint of every conceivable color. Many of these finishes can be changed to provide a new color or appearance as desired.

Climate is very important in determining how long wood and finished wood will last outdoors. The high temperatures and humidities and abundant rainfall of the southern United States are particularly hard on outdoor wood. Such exposure can increase wood deterioration, cause decay, and promote the growth of discoloring mildew on wood and finished wood surfaces. Thus, special finishing requirements must be addressed if wood used in southern exposures is to perform to its best advantage.



Proper finishing is essential in high-moisture climates. For example, Sample A was treated with a water-repellent preservative and then painted, while Sample B was not treated before painting. Both treatments were weathered for 5 years.

Research at the Forest Products Laboratory (FPL) has developed recommended procedures to ensure maximum service life and desired esthetic qualities for various wood product/finish combinations. To aid southern wood users, the FPL, working with the Southern Region of the USDA Forest Service and the Cooperative Extension Service, developed an extensive technology transfer plan. The program seeks to assist researchers and extension specialists at several southern universities in providing wood finishing information aimed at the unique problems of the South. Training seminars for wood technologists and extension specialists are being developed to assist those professionals in answering the questions. Pamphlets, books, video tapes, and slide/tapes on all aspects of exterior wood finishing are also being developed and will be distributed through the Cooperative Extension Service at participating universities.

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References

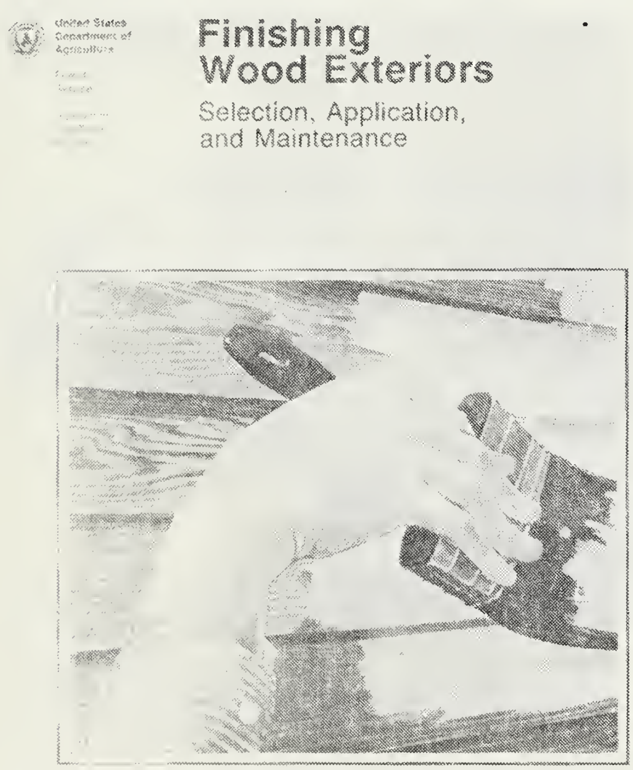
Cassens, D.L.; Feist, W.C. 1986. Finishing wood exteriors: Selection, application, and maintenance. Agriculture Handbook No. 647. Washington, DC: U.S. Department of Agriculture.

Feist, W.C. 1987. Finishing of wood. In: Wood handbook: Wood as an engineering material. Agriculture Handbook No. 72, rev. Washington, DC: U.S. Department of Agriculture. Chapter 16.

TECHLINE
Biodeterioration and Protection

Finishing Wood Exteriors: Agriculture Handbook No. 647

Finishing Wood Exteriors: Selection, Application, and Maintenance, Agriculture Handbook No. 647, brings together the results of more than 60 years of continuing Forest Products Laboratory research on exterior wood finishing. This practical, 56-page handbook is a very useful guide for do-it-yourself homeowners and also serves as a valuable reference work for professional builders, architects, and wood finishers.



Finishing Wood Exteriors: Selection, Application, and Maintenance, Agriculture Handbook No. 647, serves as a comprehensive reference for beginners and professionals on finishing wood used outdoors.

It begins with a description of the basic characteristics of wood and reconstituted wood-based products. The handbook then focuses on the finishing and performance characteristics of wood surfaces, the manufacturing and construction practices that affect those surfaces, and the ways that various finishes interact with these characteristics. A major portion of the handbook covers the causes and cures of numerous paint failure problems.

Detailed information is given on various types of exterior wood finishes, together with the proper application procedures for each. Principal subjects include paints, solid-color stains, semitransparent penetrating stains, transparent coatings, and water-repellent preservatives. Other topics of interest include the weathering of wood, treated wood products, fire retardants, and moisture-excluding finishes. Special applications and treatments needed for wood decks and porches, fences, roofs, log structures, and marine environments are outlined.

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Price: $3.25

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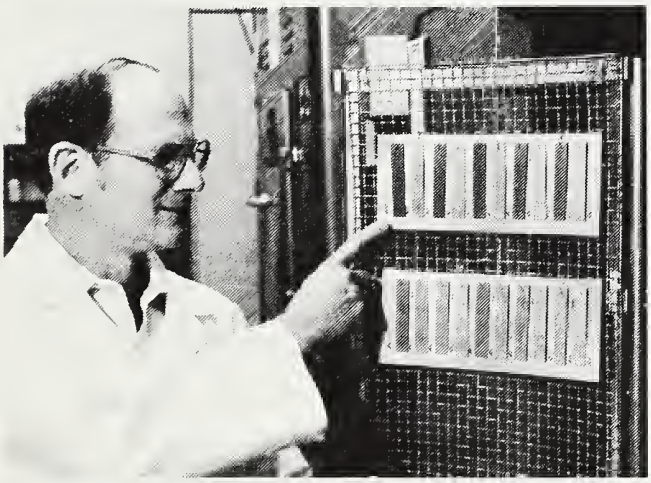
Effects of Acidic Rain on Wood and Painted Wood

Acidic rain (which can include snow, fog, and other atmospheric deposition) and/or its precursors are suspected of causing more rapid deterioration or weathering of many materials. Researchers at the Forest Products Laboratory (FPL), in cooperation with the Atmospheric Research and Exposure Assessment Laboratory of the Environmental Protection Agency, Raleigh, North Carolina, are investigating the incremental effects of acids on the weathering of wood and painted wood. Even minor deterioration may result in considerable economic loss because of the large number of painted buildings, fences, signs, and other wood materials exposed outdoors.



The difference in the appearance of these wood specimens is caused by the acid versus nonacid treatment they received during exposure in the weathering chamber.

Researchers at FPL have found that brief exposure of wood to acid during accelerated weathering increased the deterioration rate. The rate was affected by the strength and type of acid. Under conditions similar to the severest acidic condition measured outdoors, the wood surface eroded twice as fast as a similar surface that was exposed to distilled water. This more rapid weathering will shorten the service life of unpainted wood and may also affect the performance of painted wood.

The results of this research are being reported through the scientific literature and will be incorporated in documents prepared by the National Acid Precipitation Assessment Program (NAPAP) for presentation to the President and Congress. These NAPAP reports will provide the technical background for decisions regarding acid rain legislation.

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References

Feist, W.C. 1987. Finishing of wood. In: Wood handbook: Wood as an engineering material. Agriculture Handbook No. 72, rev. Washington, DC: U.S. Department of Agriculture. Chapter 16.

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Wood–Nonwood Composites

Combining wood with other materials to form new wood–nonwood composites is a very active research field. Researchers are investigating the properties of composites made by combining various species of wood, including aspen, with other biomass materials, metals, plastics, glass, and synthetic fibers. These new composites could be marketed as low-cost substitutes for more costly materials or in applications requiring specific performance attributes. These attributes can be superior to those of either the wood or nonwood component alone.

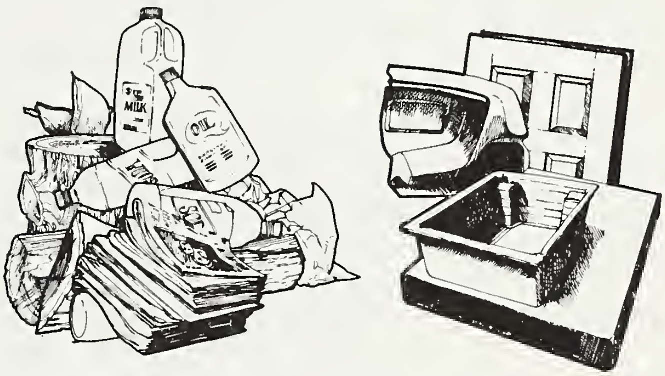
Wood–nonwood combinations have many advantages. The low density of lignocellulosics (relative to mineral fillers) provides greater volumetric effectiveness. Combining wood, agricultural residues, or chemically modified lignocellulosics with plastic provides lighter weight products with potential for controlled biodegradeability and improved acoustical, impact, and heat-reformability properties. These features are possible at costs potentially lower than comparable plastics-only products, making them competitive for many applications. Lower-cost, recycled resins would make them even more competitive.

The composites' potential for improved properties also creates a market for a variety of value-added products. The wood component can be made from low-grade wood, wood residues, and recycled newspaper, which currently have limited commercial uses. The plastic component can come from recycled material, reducing a critical waste disposal problem.

Many wood-based products have been or could be displaced by new materials such as plastics, metals, cement products, and ceramics. The high efficiency achieved by many nonwood industries depends on improved process systems and the amenability of metals and plastics to high-speed automated machines. Some of these same high-speed processing concepts can effectively utilize wood in one form or another and are very amenable to high-speed processing. The Forest Products Laboratory is actively investigating two of these processing concepts.

One processing option for wood–plastic combinations is extrusion or injection molding technology. Thermoplastic resins are thoroughly mixed with finely ground wood fibers or flour, then forced through a die to form a sheet product. The sheet can be processed in a secondary manufacturing operation into a number of molded, corrugated, or shaped sections. This technology requires an optimum component mix before product formation.

Another processing option involves blending a high percentage of natural fibers with synthetic thermoplastic or thermosetting fibers to form a nonwoven mat. The mat can be handled in roll form, permitting automated handling and processing in subsequent operations. The mat composition can be varied to produce products with specific desired characteristics. After forming, the mat can be fabricated into panel products or deep-drawn molded configurations.



Wood–nonwood composites can turn recycled paper, plastic, and wood residue into useful products through automated, high-speed processing systems.

The increased processing flexibility inherent in both the extrusion and nonwoven technologies creates a host of "new" natural fiber/synthetic fiber products. Their thickness can range from a material as thin as 3 mm to structural panels several centimeters thick. The many possible configurations fall into three major classes: packaging products, manufactured products, and corrugated or sandwich-type configurations for floor, wall, and/or roof components. A broad range of cost-effective, value-added products could be produced for each of these applications using different combinations of raw materials to produce unique performance properties.

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TECHLINE
Engineering Properties and Design Criteria

Strength of Visually Graded Structural Lumber

Procedures for assigning allowable strength properties to visually graded lumber were initially established about 50 years ago. They involve testing small pieces of defect-free wood and then modifying the resulting strength estimates. Adjustments are made for knot size and other naturally occurring growth characteristics and for such factors as moisture content, duration of anticipated load, and manufacture and use considerations. This procedure has served the public well over the years. However, modern wood structures are being engineered more precisely and better estimates of structural lumber strength are required.

The Forest Products Laboratory, in cooperation with representatives of the lumber industry, is nearing completion of the "In-Grade" testing program. The objective of this program is to develop strength data from tests of full-size lumber already graded for sale to the public. The program is divided into two parts. The first involves overall strength property evaluations; the second studies the effect of variables such as moisture content and temperature on lumber strength.

The evaluation part of the In-Grade program tested over 42,000 pieces of lumber, representing 21 softwood and 3 hardwood species. The results indicate that visually graded lumber in 2 by 4 sizes is stronger than currently estimated. The study indicates, however, that wider width lumber may not be as strong as currently assumed.

In the second part of the program, new procedures have been developed for adjusting lumber properties for change in moisture content. The new research indicates that tensile strength parallel-to-the-grain, a property important in the design of wooden trusses, is not nearly as sensitive to changes in moisture content as previously assumed.

The results of the In-Grade program are being evaluated by industry representatives and American Society for Testing and Materials (ASTM) consensus committees to achieve a much improved assignment of allowable properties for structural lumber in the United States. Many of the procedures developed in the program are also being used in Canada to develop improved property estimates for Canadian lumber.

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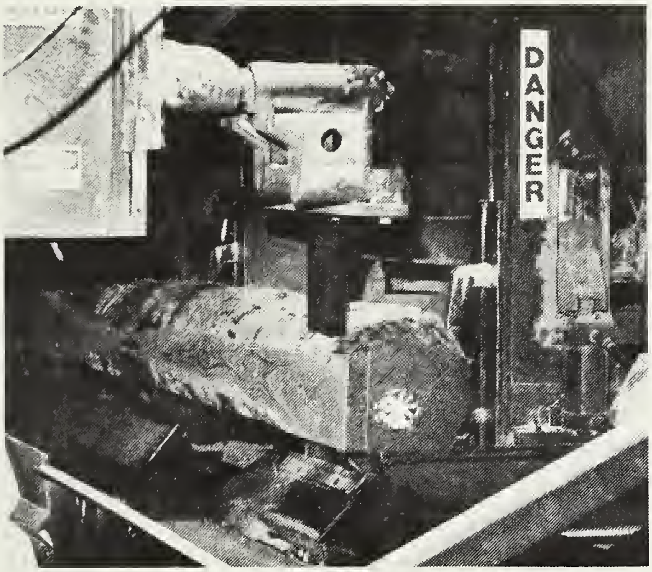
TECHLINE

Engineering Properties and Design Criteria

Hardwoods for Structural Lumber



Structural lumber produced from hardwood species may be economically competitive as lower-quality hardwoods become more abundant and research resolves technical problems.

For many years, the primary source of lumber for residential, commercial, and industrial construction has been softwood species. Hardwoods have commonly been used for higher-valued products such as furniture and cabinetry. Now, however, lower-quality hardwoods not well suited for these demanding uses are abundant. This timber resource appears suited for structural application and may be economically competitive with the softwoods in the structural lumber market.

Research has resolved many of the technical problems associated with the manufacture of dimension lumber from hardwoods, notably excessive warp and twist. (A Techline on the Saw–Dry–Rip Process is available.) Within the past 10 years, the American Lumber Standards Committee (ALSC) approved structural grading rule descriptions and allowable design stresses for four lower-density hardwood species (red alder, cottonwood, aspen, and yellow-poplar) and several higher-density hardwood species or species groups (red maple, mixed maple, beech–birch–hickory, mixed oak, red oak, northern red oak, and white oak).

Despite the removal of many technical barriers, structurally graded hardwoods are not generally available in the market. Potential producers still face uncertainties of competition with softwood lumber, pricing of hardwood lumber, and expected profit margin. These economic questions are further complicated by consumer tendency to stay with familiar products.

Despite this, the outlook for hardwood dimension lumber has never been more favorable. Increasing demand, both domestic and international, for dimension lumber and changing trade agreements with Canada are expected to severely pressure the softwood forest inventories in the United States. Research continues to remove some of the final technical barriers to hardwood use.

Mill owners must now examine all variables of economic feasibility such as log and stumpage prices, yields and product values, the costs of processing hardwoods, and capital investments for conversion of existing facilities to hardwood production or building a new mill specifically for producing hardwood dimension lumber.

The Forest Products Laboratory has just initiated research to evaluate the yield of machine stress-rated and visually graded dimension lumber from red oak logs versus alternative uses for these logs. This information will help sawmill operators select the most profitable alternative for processing hardwood logs.

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TECHLINE
Engineering Properties and Design Criteria

Corrosion of Metals by Wood Products

Wood and metal are compatible in most construction and furniture uses and few corrosion problems occur. However, if there is sufficient moisture at the wood–metal interface such as around nails, spikes, screws, bolts and plates, some corrosion can be expected with metals used commonly in construction. Corrosion of the fastener often leads to deterioration of the wood and causes loss of strength to the joint and to the structural integrity of the assembly.

This corrosion is an electrochemical process. The exposed head of a nail or other metal fastener acts as the cathode and the embedded shank acts as the anode of an electrical cell. The rate and amount of corrosion depends on the metal, conductivity of the wood, temperature, and duration of the moist conditions. The risk of corrosion depends somewhat on the species, presence of external corrosive contaminants, and whether the wood has been treated with certain preservative or flame-retardant chemicals.

This nail removed from barn siding shows the corrosion possible when metal fasteners are used under moist conditions.

Most woods are slightly acidic, with a pH of 3 to 6. In some species, acid from naturally occurring acetyl groups is responsible for the low pH, but other organic acids can also cause acidic conditions. Acetic acid is volatile and is responsible for corrosion inside of closed wood containers and plastic-wrapped wooden pallets. Common metal parts stored or shipped on wood pallets covered with plastic film should be checked carefully for the possible formation of corrosion due to the volatile acids in fresh wood. Wood treated with waterborne preservatives is corrosive to some metals in moist conditions because of the copper salts in the preservative.

Scientists at the Forest Products Laboratory have studied causes and rates of corrosion in wood and preservative-treated wood. Treated wood samples containing fasteners of various metals and alloys were placed in moist exposure conditions beginning in 1973 and were periodically inspected.

For untreated wood used in damp conditions, studies found that metals resistant to corrosion should be specified and individual fasteners exposed to water should be countersunk and covered with plugs of the same species of wood. Metals hardened to Rockwell C hardness of over 30 may suffer corrosion cracking in moist wood. To prevent dissimilar metal corrosion, two different metals should not be used for fasteners. Results showed that for use with ACA- and CCA-treated wood in moist conditions, metals that are cathodic to copper in the galvanic series should be chosen.

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References

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TECHLINE
Engineering Properties and Design Criteria

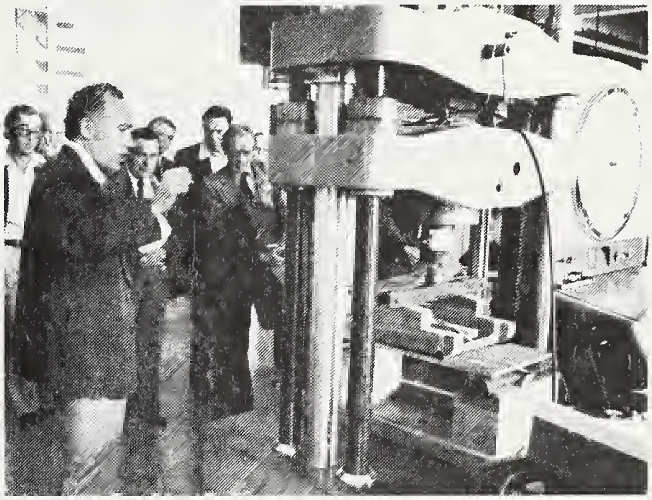
Clark C. Heritage Memorial Series on Structural Uses of Wood

The legacy of a wood products pioneer is helping engineers and architects better understand the structural uses of wood. Clark C. Heritage was an early leader in pulp and paper research at the Forest Products Laboratory (FPL). He also served for many years as the director of wood products for the Weyerhaeuser Company. Heritage died in 1972 and willed a portion of his estate to the Forest Products Laboratory for the purpose of advancing the science of wood utilization. His bequest underwrote a four-volume series of teaching modules called the Clark C. Heritage Memorial Series on Wood. The FPL produced the modules in cooperation with University of Wisconsin-Extension, Madison.

Clark C. Heritage, an early leader in pulp and paper research at FPL and later director of wood products for Weyerhaeuser. His legacy funded development of the Heritage Series. (Photo courtesy of Weyerhaeuser Company)

The development process incorporated a unique "peer review" system and integrated the resources of the Educational Modules for Materials Science and Engineering (EMMSE) project (renamed the Materials Education Council in 1984) established at the Pennsylvania State University. In the EMMSE approach, educational modules that include lecture material and self-tests are prepared by scientists, professors, and consulting engineers. These modules are then intensively reviewed by a workshop of carefully selected educators who serve as "students," first reading the modules as homework, then listening to the text presentation in a classroom setting. Subsequent revisions incorporate the educators' changes and comments. This interaction helps assure that the modules are both technically accurate and educationally appealing.

Volume I, "Wood: Its Structure and Properties," 1981, discusses in nine modules the basic insights into the structure, treatment, and properties of wood.



Former FPL Engineering Mechanics Lab supervisor Curtis Peters explains a test procedure to Heritage course members.

Volume II, "Wood as a Structural Material," 1982, describes both old and new wood materials and their uses as structural materials in eight modules.

Volume III, "Adhesive Bonding of Wood and Other Structural Materials," 1983, covers the rapidly expanding application of adhesively bonded wood products and structures through nine modules.

Volume IV, "Wood: Engineering Design Concepts," 1987, comprises eight modules that provide information and data on design of major structural members.

The Heritage Memorial Series on Wood can help engineering and materials science professors prepare state-of-the art courses on wood's utility in construction and design. These volumes will serve as an invaluable source of knowledge for tomorrow's engineers and designers and better equip them to make improved use of wood for both traditional and new innovative structures.

To order individual volumes or the entire Heritage set, contact:
Materials Education Council
110 Materials Research Laboratory
Pennsylvania State University
University Park, PA 16802
(814)865-1643

Volumes I-III are $24.00 each, Volume IV is $34.00. The entire four-volume set is $95.00. (Shipping is $2.50 per set in the U.S., $3.50 per set overseas.)

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TECHLINE
Biodeterioration and Protection

Fixation of CCA in Wood

Consumers readily accept wood products treated with chromated copper arsenate (CCA) because the waterborne treatment protects against decay and insects for a long time, leaves a clean, finishable surface and few use restrictions are necessary. Most experts believe CCA lumber (also known as pressure-treated or salt-treated lumber and by various trade names) that has been properly treated and conditioned is safe in use. By some estimates, one-third to one-half of all southern pine lumber is treated with CCA.

When the water-based, CCA-treating solution permeates the wood, the active chemicals undergo a series of reactions with and within the wood that greatly reduces the solubility of the CCA components. These reactions are temperature-dependent, virtually stopping at temperatures at and below freezing. Before the fixation reactions are complete, the preservative is susceptible to leaching and the potential for hazardous exposure of people to toxic chemicals is greatest.

Understanding how CCA chemicals become fixed in wood may allow researchers to predict other chemical preservative systems that will react similarly and perform reliably. Such understanding may also improve the current CCA system. Either approach expands the arsenal of tools for wood protection. Knowledge of fixation reactions also allows accurate determination of when preservative fixation is complete, an important consideration in consumer and woodworker safety.

In conjunction with an American Wood-Preservers' Association task force, scientists at the Forest Products Laboratory have developed a practical test that shows the completion of the chemical reduction of chromium, one indicator of fixation. Data are now being developed that should allow treated-wood producers to predict when their product will be ready to market. While outside the purview of the FPL, toxicological studies of CCA-treated wood are needed, and FPL could provide the technical liaison supporting such work.

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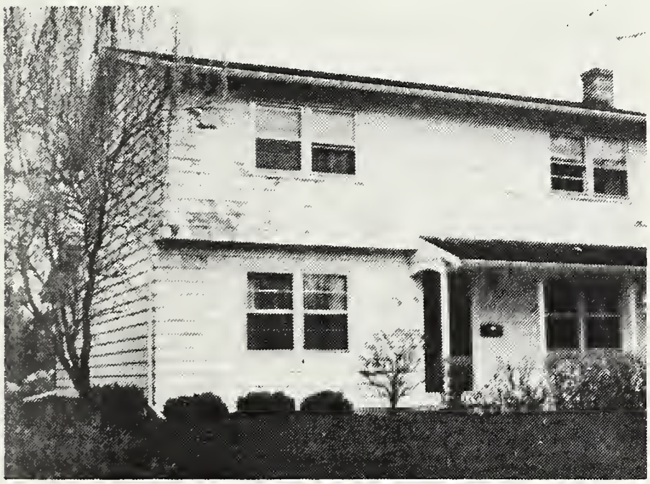
TECHLINE
Biodeterioration and Protection

Prefinish Weathering of Wood and Its Effects on Performance

The reasons for premature and catastrophic peeling of paint from wood are often difficult to determine. Researchers at the Forest Products Laboratory (FPL) are investigating several aspects of this problem. They recently determined that paint applied to weathered wood surfaces has decreased adhesive strength. Weathering for periods as short as 2 to 4 weeks before finishing caused significant losses of paint adhesion.



Weathering of building materials before finishing can lead to premature paint failure.

Such deterioration could lead to premature paint failure and means that wood should be finished as soon as possible when it is installed outdoors. If not protected by appropriate paints, stains, or other pigmented finishes, poor finish performance might result. The research results also suggest that more consideration should be given to using wood products that are factory prefinished or preprimed, as is the case with commercial hardboard products.

These basic results were already published in scientific journals. Research is continuing and will include the long-term effects of weathering on the performance of wood finishes and how different wood species respond to weathering. Results to date demonstrate for painters, contractors, and architects the importance of protecting wood from the weather before it is finished in order to ensure long life for the applied finish.

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'ECHLINE

Energy

A Wood-Fueled Pressurized Downdraft Combustor–Turbine

Utility and industrial power systems often use gas- or liquid-fueled gas turbine engines. However, the use of coal or wood to directly fuel a gas turbine has not yet become practical, primarily because the ash can adversely affect the turbine blades. If the ash in the combustion gas is molten, the ash may deposit on the blades and corrosion may occur. If the ash is solid particles, it may erode the blades. The size distribution, concentration, and composition of the ash particles will affect the operation of the turbine. Based on work with two prototype combustors, joint studies between the USDA Forest Service's Forest Products Laboratory and the University of Wisconsin have determined that important characteristics of the ash particles can be controlled with a downdraft combustor operating at high excess combustion air.

To further test these effects, a unique wood-fueled pressurized downdraft combustor was constructed and tested to determine its operating characteristics, the composition of the combustion gas, and the properties of the ash particulates.

Fuel is fed to the combustor through a lock hopper, where it is combusted on a bed of magnesium oxide pellets. It has been operated at a fuel rate of up to 100 pounds per hour with up to 200 percent excess combustion air preheated to 200°C at pressures of 1 to 5 atmospheres. An Allison Model 250 gas turbine engine has been coupled to the combustor and tests are proceeding.

Results to date indicate the combustion rate is sensitive to fuel moisture content, air preheat temperature, and pressure. The combustion gas composition depends on the combustion conditions, and over 80 percent by weight of the particulates are less than 5 microns in size. A model of the combustor–turbine–compressor system has been developed to simulate turbine operation at various combustion rates.

The U.S. Department of Energy provides major funding to the University of Wisconsin–Madison for this project. The turbine and technical consulting are provided by the Allison Division of General Motors Corporation, and technical support is provided by the USDA Forest Service's Forest Products Laboratory.

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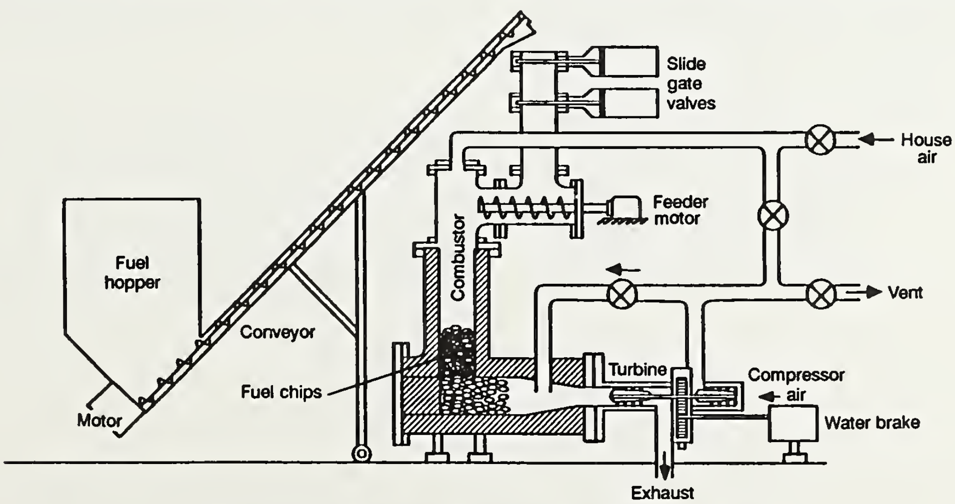


Pressurized downdraft combustor–turbine test setup.

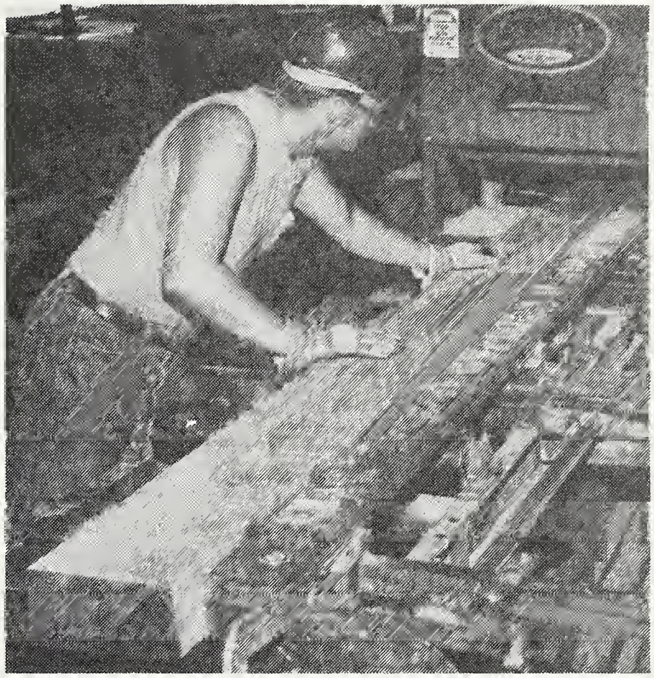
State & Private Forestry Technology Transfer Coordination

Industry and researchers must keep up with rapid changes in technology and scientific investigation. The State & Private Forestry (S&PF) technology transfer coordinator facilitates that process for USDA Forest Service forest products research. Located at the Forest Products Laboratory (FPL) in Madison, Wisconsin, the coordinator oversees activities that help transfer high-priority knowledge and capabilities and share research facilities. The projects undertaken are identified jointly by research scientists and users of technology.

The purpose of the transfer effort is to both improve the effectiveness and efficiency of the Forest Service by bringing in new technologies or to transfer existing Forest Service technologies to the commercial sector. The coordinator works closely with project leaders and assistant directors at the Laboratory and other research locations, USDA Extension personnel, and S&PF and state wood utilization and marketing specialists. Current emphasis is on identifying research activities ready for transfer and matching it with the needs of cooperators and potential users.

Two major technology transfer projects are currently underway. The first is the IMPROVE (Integrated Mill Production and Recovery Options for Value and Efficiency) System. It consists of a series of personal computer-based programs that mill operators can use to increase the efficiency of their operations. A 5-year technology transfer plan is being implemented by a combined staff of research and S&PF personnel at FPL.

The second project is the Timber Bridge Program located at the Hardwood Timber Bridge Information Resource Center, Morgantown, West Virginia. S&PF staff at the Center are currently implementing the 5-year technology transfer plan. The plan includes special funding for timber bridge research, construction of demonstration bridges, and technical assistance.



Mill operators can improve their efficiency with a series of personal computer-based programs called IMPROVE, a research product being marketed through State and Private Forestry technology transfer.

Another tool of the technology transfer program is *The Utilization & Marketing Review*. The coordinator publishes this monthly newsletter which highlights research activities, special events, meeting announcements, and items of interest to forest products users.

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TECHLINE
Microbial and Biochemical Technology

Shiitake Mushroom Cultivation

Shiitake mushrooms are cultivated commercially by inoculating a hardwood log with live fungal cells.

Some of the most underutilized forest materials are small-diameter hardwood trees and the limbs and tops of larger trees. The U.S. inventory of small-diameter hardwoods is increasing due to the lack of suitable outlets. Profitable uses are needed for this material so that selective thinning becomes economically attractive to improve stagnated forest stands.

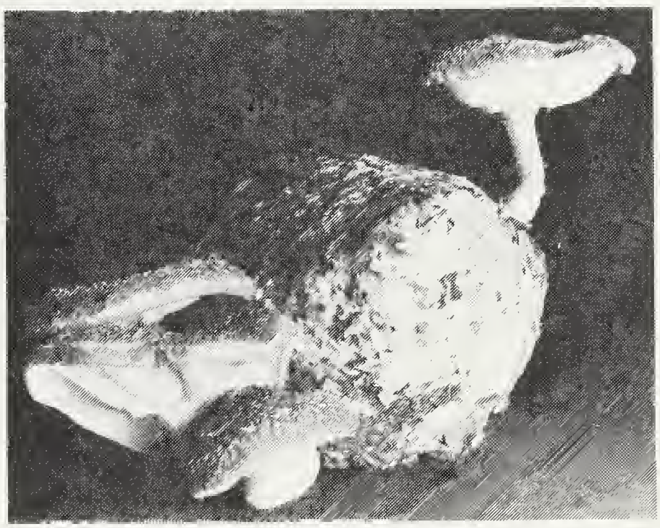
A promising alternative now emerging in the United States is the conversion of this material into a new high-value forest crop—the edible shiitake (she-ee-ta-kee) mushroom. Shiitake is already the major cultivated mushroom of the eastern hemisphere. Japan alone produces over $1 billion of shiitake annually as one of their leading agricultural exports.

Over the past several years, researchers at the Forest Products Laboratory have been transferring the existing Oriental technology to the United States and studying the cultivation of shiitake on domestic hardwoods (such as oak) and certain agricultural lignocellulosic materials (such as corn cobs).

Shiitake can be cultivated on either small-diameter hardwood logs (2- to 8-inch diameter) or on particulate media, such as hardwood sawdust, with or without the inclusion of other lignocellulosic materials. Yields from logs can be as high as 9 to 35 percent fresh-weight mushrooms per fresh-weight logs over a 3- to 8-year period. Yields from particulate media can be as high as 50 to 140 percent fresh-weight mushrooms per dry-weight medium over a 3- to 9-month period.

The cultivation of shiitake on logs starts with harvesting the trees during winter or early spring and cutting them into convenient-length logs. The shiitake producer then drills openings in the logs and inoculates them with living fungal cells (spawn). He incubates the logs in stacks to allow the fungus to colonize and then restacks the logs for fruiting and harvesting the crop. The colonization and/or fruiting can be done either out-of-doors (traditional method) or indoors (forced-fruiting method). Soaking the logs in water can be used to stimulate fruiting and boost mushroom yields.

Shiitake is cultivated on particulate media in controlled chambers with carefully regulated environments. The media is prepared, sterilized, and inoculated with a suitable fungal strain. The fungus colonizes the media, which typically is kept in plastic bags to keep the cultures free of contaminants. Once colonized, the fungal culture is removed from the containers and the conditions in the growth chamber are changed to ensure mushroom production.



Shiitake mushrooms can also be grown commercially on particulate media such as hardwood sawdust.

Shiitake cultivation is gradually becoming established throughout the United States and is expected to be an excellent growth industry for the next several years. The first shiitake national symposium and trade show was held in May 1989.

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'ECHLINE
Pulp, Paper, and Packaging

CTMP Press Drying Computer Model

Research at the Forest Products Laboratory (FPL) established the potential for using hardwood chemithermomechanical pulp (CTMP) in conjunction with the FPL press drying papermaking technique to produce a linerboard for corrugated boxes. The press-dried CTMP linerboard is comparable in quality with conventional unbleached kraft linerboard. Unbleached kraft pulping uses mostly softwoods and currently accounts for roughly one-third of all pulpwood consumed in the U.S. pulp and paper industry.

The CTMP process offers several advantages over the traditional process. The CTMP process requires one-third less pulpwood to yield the same quantity of pulp and has much lower capital investment costs than conventional kraft pulping. Although the higher-yield mechanical pulps, such as CTMP, have been regarded as weak, the FPL press drying process overcomes this limitation, producing a high-strength sheet even from hardwood CTMP.

A disadvantage of CTMP is the high energy requirement for mechanical refining. CTMP press drying could be developed for commercial application and have profound economic consequences. However, technical questions about the economic feasibility of the overall process remain.

To address these questions, economists at the FPL modeled the economic performance of a future CTMP press drying process. The computer model includes software for multivariate stochastic simulation and deals with numerous process variables. Because of uncertainty about commercial application and future economic circumstances, some of these variables are treated as random in their possible outcomes. These variables are represented in the simulation as probability distributions of expected outcomes. Some of these same variables are correlated, and the model includes assumptions regarding correlation coefficients among the variables.

Multivariate simulation derives a probability distribution for the expected economic performance of the future technology. The result shows how the variability and correlation among underlying technical assumptions will influence the range and likelihood of possible economic outcomes.

The study is scheduled for completion in 1990. Results of the simulation analysis will be published, and should interest researchers and technologists in the pulp and paper industry. The computer simulation software will also be made available, including generally applicable software for multivariate stochastic simulation. The multivariate stochastic simulation has broader applications of interest to economists in forest products and forestry research.

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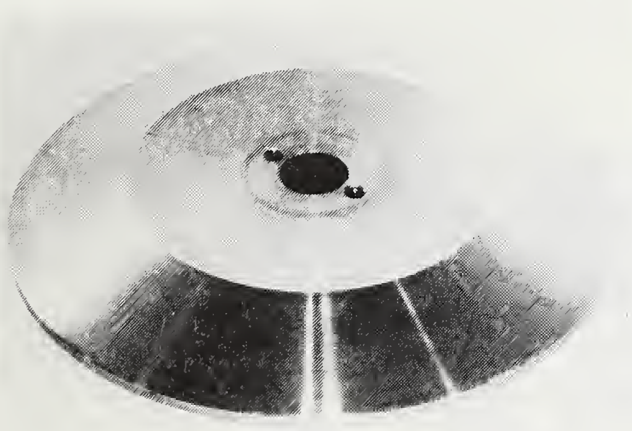
Disk Separation

Nonwettable adhesive contaminants have been a major obstacle in wastepaper recycling. Sometimes these contaminants, which papermakers call "stickies," adhere to papermaking equipment, and sometimes they show up as undesirable spots in the paper product. Scientists at the Forest Products Laboratory (FPL), working in cooperation with the University of Wisconsin (UW), have developed a device that improves the removal of stickies from wastepaper.

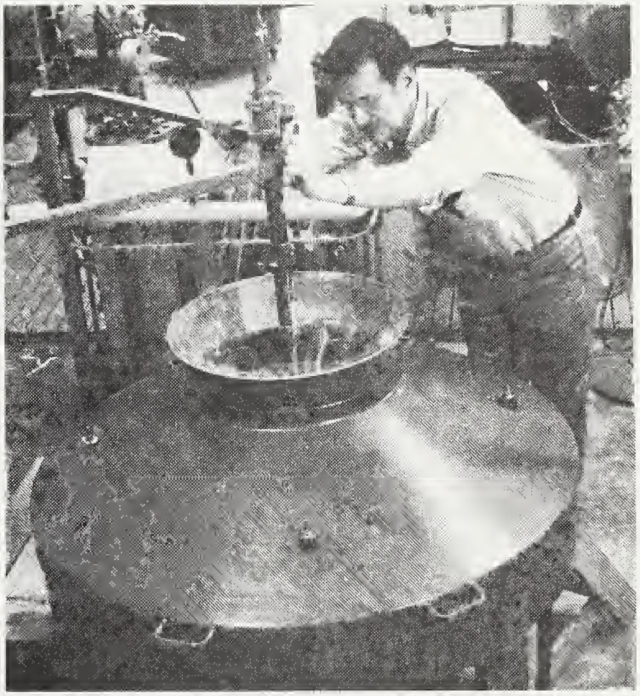
Adhesive particles are a problem because they are about the same size and density as wetted pulp particles. Typical recycling separation processes separate on the basis of size or density differences. Thus, adhesive particles traditionally remain in the pulp slurry. However, in experiments, a smooth, wide-lip disk spinning at high speeds separated particles based on their size, density, and wettability differences. These tests demonstrate that disk separation can remove high levels of nonwettable contaminants, without significant fiber loss.



Key component: Wide-lip spinning disk.

The major technical obstacle remaining is increasing the throughput of the process. Fabrication of equipment with practical throughputs seems likely, given this information and results from some current fundamental studies.

By successfully demonstrating how sticky contaminants may be removed from wastepaper, FPL scientists have made progress in overcoming the main obstacle to efficient recycling. This is highly important to the paper industry. FPL economists have shown that it is much less expensive to increase pulp production capacity by adding recycling equipment than by constructing a new pulpmill. Recycling also extends the Nation's timber supply by recovering wood fiber that is now being landfilled.



FPL scientist John Klungness adjusts flow of wastepaper pulp slurry entering the experimental disk separator.

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'ECHLINE

Wood Bonding Systems

Resin Characterization

Development of an adhesive for a specific wood-bonding process can be a long process of trial and error without knowledge of the curing and bonding characteristics of the resin. Researchers at the Forest Products Laboratory and the University of Wisconsin are developing methods to characterize a thermosetting resin's response to varying conditions of temperature and moisture. The information gained from these new methods should help resin manufacturers tailor adhesives for specific applications.

A dynamic mechanical analysis (DMA) determines the extent of mechanical or physical cure after a resin-coated glass cloth sample is exposed for various times to controlled conditions of heat and moisture. Comparing these results to differential scanning colormeter (DSC) measurements indicates the extent of chemical cure occurring in the resin during the same exposure treatments.

Experiments to date indicate that mechanical cure may progress at a different rate than chemical cure and that the relationship between curing rates varies with resin types. Initial investigations also show that higher moisture (relative humidity) levels increase the rate of cure for some resins while retarding cure for others.

Further investigations will be made to (1) characterize resin bonding performance under various conditions, (2) measure the environmental conditions in a pressed composite mat, and (3) further determine chemical changes occurring in the resin through the use of nuclear magnetic resonance (NMR) and infrared (IR) spectroscopy. This information will enhance knowledge of the environmental conditions that occur during a gluing operation and the chemistry of a resin, which dictates its response to these conditions.

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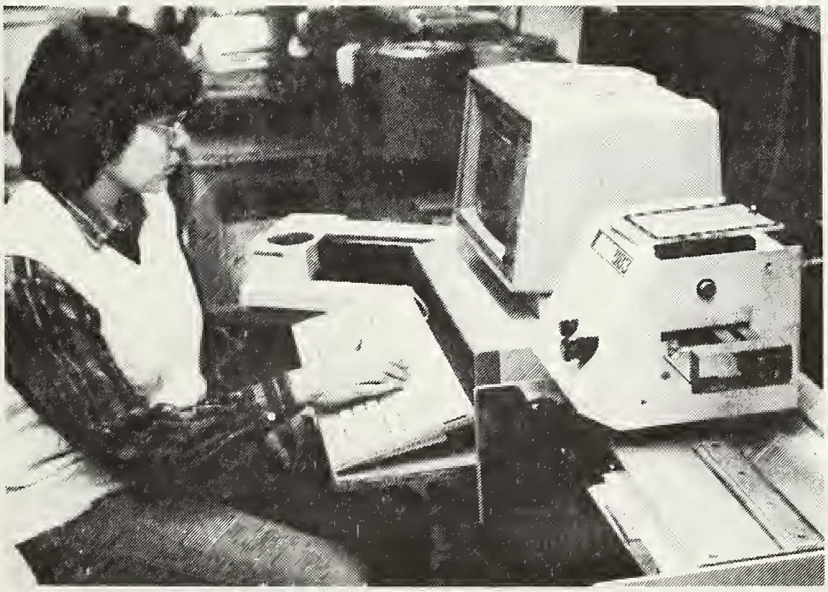

Dynamic mechanical analysis on this equipment helps determine the extent of mechanical and physical cure rates for various resins.

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TECHLINE
Fire Safety

Fire Resistance of Structural Wood Products

Intumescent coatings, which swell up when exposed to heat, are one of the types of fire resistive coatings being studied at the Forest Products Laboratory.

In developing or using structural assemblies, a design must meet code requirements that specify the fire resistance ratings required for a given occupancy and type of construction. Fire resistance ratings relate to the ability of the wall or floor assembly to act as a barrier to the fire and contain the fire within the room of origin. Standard testing procedures expose an assembly to a specified fire exposure to determine how long it can withstand the fire. Listings of rated assemblies are available from various sources. These tests are extremely costly and the ratings do not provide flexibility to alter the design of the assembly.

Researchers at the Forest Products Laboratory (FPL) are developing analytical procedures that will permit such design flexibility. Current efforts are concentrating on models for parallel chord truss floor systems and wood joist floor systems. Past work has resulted in analytical procedures for walls, unprotected joist floors, glued-laminated timbers, and unprotected floor trusses.

Two procedures for rating wood assemblies' fire resistance have gained U.S. and Canadian building code acceptance. The component additive calculation procedure conservatively determines the fire resistance ratings of light-frame assemblies. The 1-hour fire resistive exposed wood member procedure rates large wood members with minimum nominal dimension of 6 inches. Both of these procedures were developed by the National Research Council of Canada and have been introduced into the U.S. building code as a result of efforts by the National Forest Products Association. These and other procedures are described in a chapter of the SFPE Handbook of Fire Protection Engineering on "Analytical Methods for Determining Fire Resistance of Timber Members." A 1988 update is also available. More information on fire safety of light-frame structures is in FPL–GTR–59.

The typical method of improving the fire resistance of a wood assembly is to add a gypsum board membrane. FPL researchers are continuing to evaluate fire resistive coatings as an alternative. Empirical equations have been developed for predicting the performance of such coatings in different applications.

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'ECHLINE
Fire Safety

Fire Hazard Assessment for the Wildland/Urban Interface

As demonstrated by recent severe fire seasons, the hazard from forest fires increases as people build more residences in rural areas. Firefighters now must defend both these residences and the forest. This dual role increases firefighting costs and may result in a greater loss of the natural resource. Unfortunately, homeowners may not take the hazard of fires into consideration as they build their dream homes on scenic sites among the trees.

To reduce the fire hazard where the city meets the woods, homeowners, developers, and builders must know what structural designs, building materials, and landscape vegetation reduce fire risk within the natural setting. But this requires knowledge of the fire hazard of various structural and landscape designs and building materials.

One approach to creating this awareness ranks the relative hazard from forest fuel, structural design, landscape, terrain, potential mitigation, and the distance of the structure from the forest fuel. Researchers at the Forest Products Laboratory are developing such a methodology for the wildland/urban interface. The method links the intensity of the wildland fuel potential with the potential hazard of the structure. Research is currently in progress.

Although currently being developed for California, in cooperation with the California Division of Forestry and the California Fire Marshall's Office, the assessment procedure could be extended to other geographical areas.

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Residences in forested settings risk destruction by forest fire, a hazard homeowners may not have considered at the time of construction.

ECHLINE

Engineering Properties and Design Criteria

Effects on Wood Strength of Redrying and Waterborne Preservative Treatment

Waterborne preservative treatment of wood produces a clean, odor-free, paintable/stainable product. Yet, waterborne preservatives can reduce wood strength. The extent of this effect depends on several key factors, such as preservative chemical, redrying temperature, species/grade/size, and incising. Researchers at the Forest Products Laboratory are studying how each of these factors affect lumber properties.

The relative impact of a waterborne preservative relates directly to its chemistry and the severity of its fixation/precipitation reaction. Studies have shown that ammoniacal copper arsenate (ACA) and ammoniacal copper zinc arsenate (ACZA) affect strength less than chromated copper arsenate (CCA). The impact of various CCA formulations appears to be related to chromium content.

All terrestrial retention levels appear to have similar effects on strength when redried at comparable temperatures. However, the higher retentions required for marine use (2.50 lb/ft^3) do significantly reduce bending and impact strength and reduce compression strength when redried at 140°F.

Waterborne preservatives permit new wood uses, such as this wood foundation, but can also reduce strength properties. (Photo courtesy of Southern Forest Products Association)

Redrying temperature appears to be the most decisive single processing factor affecting strength. The higher the redrying temperature, the greater is the negative effect on mechanical properties. Air drying after treatment appears to have little practical effect on strength.

It appears that no differential species effect exists. Generally, higher grades are reduced in strength more than lower grades; smaller sizes more than larger sizes.

Incising is used with difficult-to-treat species to improve preservative penetration and distribution. Incising reduces strength. However, this strength loss is more than offset by the improved performance of the incised treated product. The technical literature supports a 10 to 20 percent reduction in allowable design stresses for 2-inch-thick lumber and a 0 to 10 percent reduction for thicker material.

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Bendtsen, B.A.; Gjovik, L.R.; Verrill, S. 1983. The mechanical properties of salt-treated longleaf pine. Res. Pap. FPL-RP-434. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

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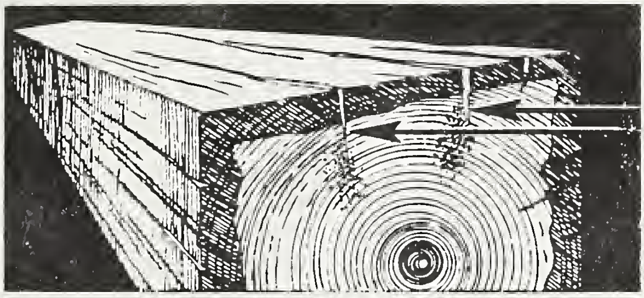
United States Department of Agriculture | Forest Service | State and Private Forestry | Forest Products Laboratory

9001

TECHLINE
Biodeterioration and Protection

Eradicating Decay in Exterior Timbers

Large, exterior structural timbers are usually pressure treated, but deep seasoning checks can develop that penetrate the treated shell. Water for the growth of decay fungi is trapped in the checks, and the result is interior decay.

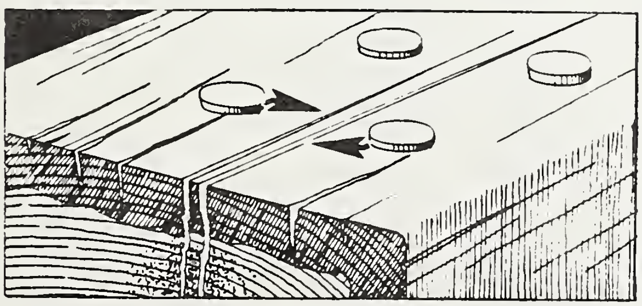


Decay originates in deep seasoning checks.

Preservatives applied by ordinary flooding from a brush or spray penetrate the wood only slightly and so cannot stop this decay. Research at the Forest Products Laboratory has shown that fumigants such as Vapam (sodium N-methyl dithiocarbamate), chloropicrin (trichloronitomethane), and methylisothiocyanate (MIT) applied to holes drilled in the timbers and plugged can stop internal decay.

Before applying the fumigant, timbers must be inspected thoroughly to determine drilling patterns that avoid metal fasteners, seasoning checks, and severely rotted wood. Holes are drilled straight down to within about 1 inch of the bottom and can be clustered in the top or in pairs.

Treatment holes should be no more than 4 feet apart. The amount of chemical needed and the size and number of treating holes required depends on timber size. For example, a 7- by 8-inch timber can be protected by applying 0.13 pint (60 ml) of Vapam or chloropicrin into four equally spaced holes above a decayed area.



Treating holes should be situated on both sides of checks.

Liquid fumigants can be squirted into the holes with a 1-pint polyethylene squeeze bottle. Solid fumigants can be applied with a special device that does not expose the applicator to the chemical. The treater must wear protective clothing and work upwind of the timber being treated. Immediately after adding the fumigant, the holes are plugged with preservative-treated dowels or rubber stoppers. Enough room must be left in the treating holes so that the plugs can be driven in without squirting the chemical.

Eventually, these fumigants lose effectiveness and retreatment is necessary. When this happens varies. Chloropicrin will remain effective for 10 or more years whereas Vapam and MIT-treated timbers need retreatment in about 5 years.

The use of trade or firm names is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

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This document reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

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9001

Behavior of Mineral Matter of Wood During Combustion

Minerals are an essential nutrient for tree growth which remain in the wood when the tree is harvested. If the wood is burned, ash particulates are formed from that mineral matter. Little is known about the chemical and physical behavior of mineral matter in wood when it is burned, compared with the extensive investigations on coal and other fuels. Knowledge of the basic processes in the transformation of wood mineral matter to ash can lead to improved designs of boilers and combustors resulting in improved efficiency and durability.

The Forest Products Laboratory (FPL) and the University of Wisconsin–Madison are studying the effects of temperature and residence time on mineral matter volatile release and particulate matter formation. The volatilization and condensation of potassium, calcium, phosphorus, sodium, silica, and other mineral substances in wood and bark are being studied in a tube furnace using scanning electron microscopy (SEM), electron spectroscopy, and differential thermal anaysis of wood ash. The formation of particulate matter nodules on the surface of wood and bark char will be studied in situ using fiber optics and SEM.

This study should develop basic information about how wood ash particles form, their chemical nature, and how chemical composition affects the temperatures at which ash becomes molten and volatile.

The National Science Foundation is providing major funding for this project with financial and technical support from the FPL.

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Reference

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Mineral Matter in Whole Aspen Tree
(without leaves)

Elements	Percent of tree weight	Elements	Percent of tree weight $\times 10^{-6}$
Total ash, as oxides	1.45	Iron	53.5
		Zinc	43.9
Calcium	0.416	Manganese	21.7
Potassium	0.131	Aluminum	11.4
Magnesium	0.050	Sodium	11.1
Phosphorus	0.036	Copper	9.8
Sulfur	0.0104	Boron	6.2
		Lead	1.8
		Cadmium	0.4

TECHLINE
Energy

Alcohol Production

Both ethanol and methanol (types of alcohol suitable for fuel use) can be produced from wood. Yet only about 4 to 5 million gallons of alcohol are produced from wood each year in the United States, compared with almost 1 billion gallons of fuel alcohol produced from grains.

Current commercial biomass alcohol processes derive ethanol mainly from corn. Much of it is also produced synthetically from petroleum. Methanol is produced principally from natural gas, with a small contribution from coal. Wood-derived alcohol is produced from the waste liquor of a pulping operation.

Technology for ethanol production from wood has been developed and subjected to some pilot testing. The economic competitiveness of producing ethanol from wood depends on feedstock costs and other variables. Production and marketing of byproducts (high-fructose corn syrup and distiller's dry grains from corn and molasses and furfural from wood) significantly affect this economic balance. Ethanol production from wood could be implemented fairly rapidly, should another global petroleum emergency create the need for alternative fuels. However, some additional pilot testing of the technology may be needed.

The Forest Products Laboratory and the Tennessee Valley Authority's National Fertilizer Development Center have developed and pilot tested a process for producing ethanol from low-grade hardwoods. Called the two-stage, dilute sulfuric acid hydrolysis process, it converts wood to carbohydrates that can be fermented into alcohol. The second stage of two-stage hydrolysis produces about 20 kg of carbohydrates suitable for processing to ethanol from every 100 kg of ovendry wood feedstock. The first stage produces an additional 24.9 kg of carbohydrates, but many of these first-stage carbohydrates are not necessarily fermentable to ethanol.

If xylose could be fermented to ethanol economically, fermentation of the first-stage products, xylose and glucose, could nearly double ethanol production, compared with only fermenting the glucose from the second stage. Other possible products from the first-stage carbohydrates are single-cell protein, furfural, and feed molasses.

The technology for producing methanol from wood is less fully developed than that for producing ethanol. Although methanol was once produced from wood as a byproduct of charcoal manufacture, overall yields were low. To produce methanol from wood with a significantly higher yield would require production of synthesis gas in a process similar to that used for production of methanol from coal.

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Reference

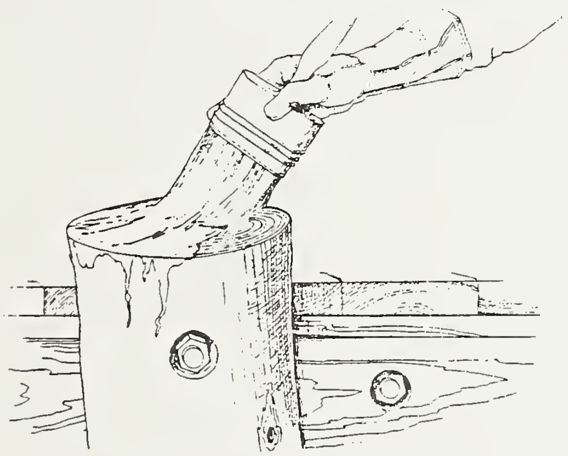
Harris, John F., et al. 1985. Two-stage, dilute sulfuric acid hydrolysis of wood: an investigation of fundamentals. Gen. Tech. Rep. FPL-45. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 73 p.

Control of Decay in Waterfront Structures

Wood is one of the most widely used materials for piers and wharves. However, marina and dock owners annually lose millions of dollars because the wood in above-water marine structures was inadequately treated. Particularly prone to decay are the heartwood portions of pressure-treated Douglas-fir fender piles and other large structural timbers with deep checks that penetrate the treated shell. Premature failure is especially serious in fender piles, which protect both the docking vessel and the pier or wharf from possible impact damage.

Recent research conducted by the Forest Products Laboratory has shown that two simple in-place treatments can prevent above-water decay and extend service life of marine pilings at least 10 years.

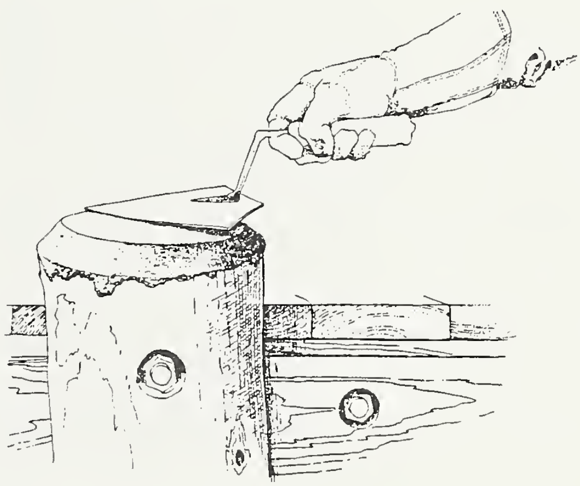
The first technique involves in-place application of either ammonium bifluoride or a fungicide in a mastic material (such as Osmoplastic (Osmose Co.) or Tritox (Koppers)) to the top surface of cut-off piles. The second technique applies a coal-tar coating "cap" on top of the treated pile.



Application of fungicide.

Douglas-fir piles achieve long-term decay protection if a 20 percent aqueous solution of ammonium bifluoride is brushed on or a fungicidal mastic is troweled on immediately after pile tops are cut off. This treatment only protects against decay starting at the top of the pile. The brush treatment with ammonium bifluoride is the easier of the two methods. Either treatment is effective by itself, and retreatment does not appear necessary for at least 10 years.

FPL researchers recommend the second step of adding a coal-tar cap to either fungicide treatment. This protective coating prevents troublesome weather checking and lengthens the inhibitive action of the fluoride treatment.



Application of coal-tar cap.

The growing replacement costs for piles, decks, curbs, fender pilings, and other waterfront structures have increased the significance of these research results. Learning to protect wood in waterfront structures is important because of wood's many unique advantages for marine use, such as high strength-to-weight ratios, resiliency, ease of construction, and relatively low cost.

The use of trade or firm names is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

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Reference

Highley, T.L.; Scheffer, T.C. 1989. Controlling decay in waterfront structures. Evaluation, prevention, and remedial treatments. Res. Pap. FPL-RP-494. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 26 p.

United States Department of Agriculture | Forest Service | State and Private Forestry | **Forest Products Laboratory**

9001

Effect of Climate on Durability of Wood

Climate has an important bearing on the relative rate of decay of wood, and thus, the service life to be expected from wood exposed to the weather. Researchers at the Forest Products Laboratory have devised a climate index map to predict relative decay hazard regions in the United States.

The map is based on mean monthly temperature and number of rainy days. The most severe location in the United States is the southeastern states where rainfall is high and the weather is warm and humid. In the Northeast and Midwest, decay advances at a somewhat slower rate. Near the coast in the Northwest, decay hazard is moderate; but on the coast, it can be severe. Most of the Southwest is very dry, so decay is less hazardous.

In mountainous regions, localized areas with marked differences in temperature and rainfall occur. Index differences due to this factor are not reflected in the map. However, where climate is relatively uniform over wide areas, the map can be used with confidence.

Homeowners, architects, builders, and marina operators can use this map to assist them in selecting the wood species or preservative treatments that will ensure maximum service life of their wooden structures.

The climate index map primarily estimates the decay hazard of wood exposed above ground to weather, but can, with certain restrictions, determine the hazard for wood in contact with the ground. It is best to consider any wood-soil contact a high hazard requiring wood pressure-treated with a preservative.

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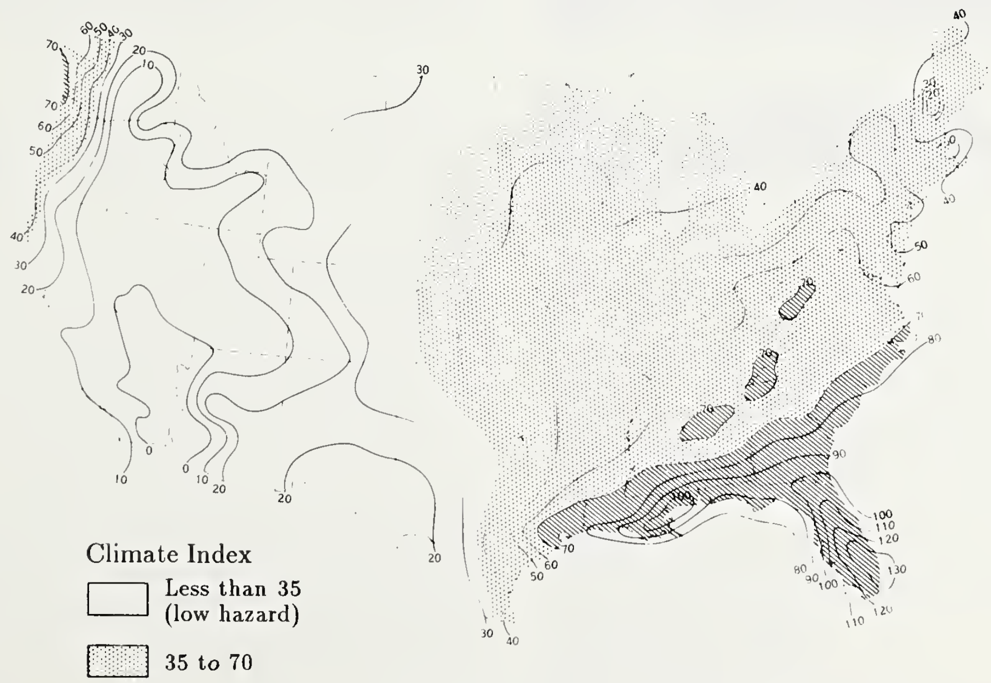
Reference

Scheffer, T.C. 1972. A climate index for estimating potential decay in wood structures above ground. Forest Products Journal 21(10):25-31.



The climate index map estimates decay hazard of wood exposed to weather above ground.

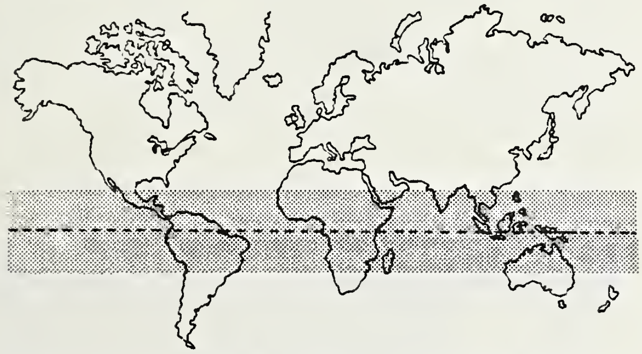
TECHLINE

General

Tropical Timbers of the World

Tropical timbers are now an established part of the U.S. marketplace. Since the early 1960s, U.S. tropical lumber imports increased fourfold and plywood trade, mostly from Asian sources, soared fortyfold, equaling domestic production. Log imports, though, decreased drastically, from about 100 million board feet (log scale) in the 1950s to about 14 million in 1987. Much of the world timber trade is now processed material.

A comprehensive reference book published by the U.S. Department of Agriculture, Forest Service describes the array of tropical wood species and species groupings now available to U.S. processors. *Tropical Timbers of the World*, Agriculture Handbook 607, describes 370 species of tropical trees and their characteristics and uses. The 464-page book includes softwoods, hardwoods, decorative species, and utility woods from three geographical areas, Tropical America, Africa, and Southeast Asia and Oceania.

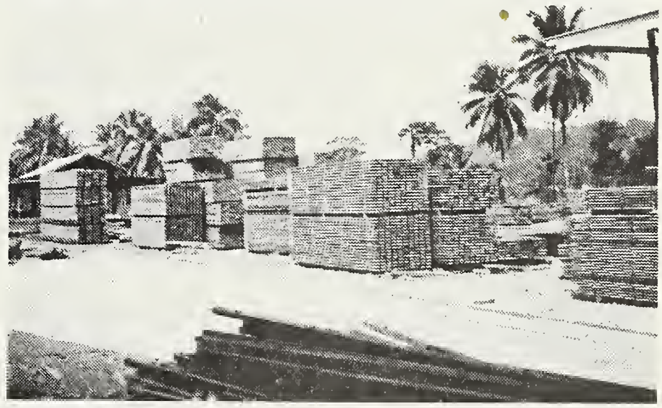


Author Martin Chudnoff, formerly of the Forest Service's Forest Products Laboratory, compiled and synthesized data from world literature and spent more than 30 years studying tropical woods.

Information on the species and species groupings includes scientific and common names, distribution, general characteristics, weight, mechanical properties, and current uses. A section of comparative tables on specific properties and end uses follows the individual species entries grouped by geographic origin. The book includes an index of trade names and important common names cross-referenced to scientific names and geographic region.

Most tropical timbers have numerous common or trade names and the original *Tropical Timbers* index generally contained only one or two of the most frequently used names. Therefore, a *Complete Index of Common Names: Supplement to Tropical Timbers of the World (AH 607)* was published in 1989. Copies of the supplemental index may be ordered from Information Services, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705–2398.

Planalto forest south of Santaren in Rio Curua-Una region, Brazil. About 60 percent of the volume is in species considerably denser than U.S. commercial woods (basic specific gravity over 0.70).



Degradation of wood products due to attack by decay fungi and insects is an ever-present hazard in the tropics. Construction lumber imported into Puerto Rico is treated with wood-preserving salts and then stacked for air-drying.

Tropical Timbers provides researchers, tropical wood processors, and importers with an invaluable, well-organized reference. The easily used book assembles detailed data not previously accessible to most users. The continued growth in lumber imports from tropical areas will increase the demand for more adequate scientific and technical data on these woods and their applications.

Copies of Agriculture Handbook 607 are available from:
U.S. Department of Commerce
National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
Order No. PB85–156917
(703) 487–4650

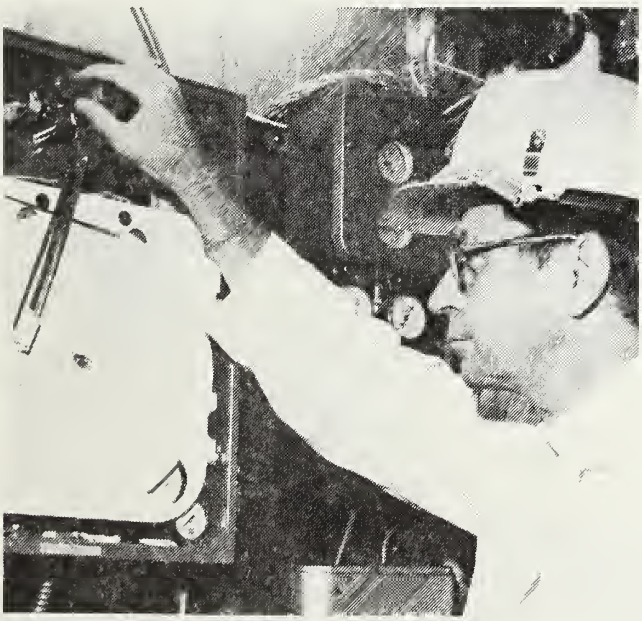
ECHLINE

Processing of Wood Products

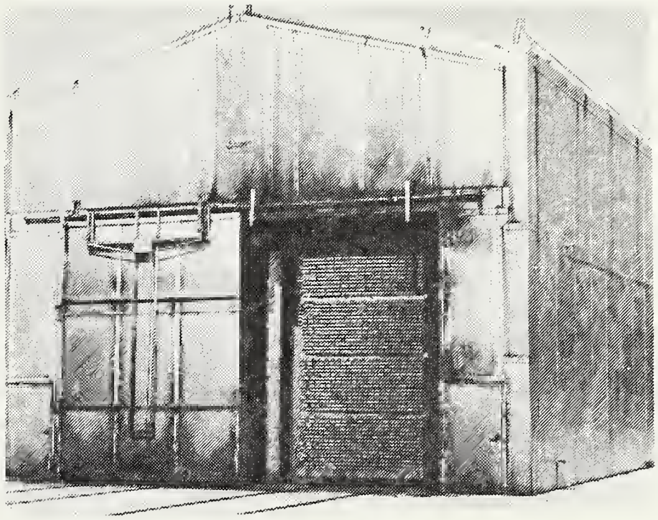
Dry Kiln Schedules for Commercial Woods

A recent publication by the Forest Products Laboratory tabulates hundreds of suggested dry kiln schedules for commercially important temperate and tropical woods. *Dry Kiln Schedules for Commercial Woods*, FPL–GTR–57, consolidates and updates drying schedules from many sources, making them easy to find and convenient to use. Previously, these schedules were scattered in many publications and often presented in a coded form difficult to decipher.

The report includes dry kiln schedules for several thicknesses of more than 500 temperate and tropical woods and, for many species, schedules for specialty products, such as wooden squares, handle stock, and gun stock blanks. R. Sidney Boone, Forest Products Laboratory; Charles J. Kozlik, Oregon State University (retired); Paul J. Bois, State and Private Forestry (retired); and Eugene Wengert, Virginia Tech, coauthored the report. In addition to revising some recommended schedules, they consolidate information from the world literature drawing mainly from U.S., Canadian, and British publications.



FPL scientist Sidney Boone adjusts the control instrument to new set points for a drying schedule.



This publication includes suggested drying schedules for high-temperature kilns such as this.

The report suggests revised schedules for some western U.S. and Canadian softwoods and for the U.S. southern pines. The report also includes the latest suggested high-temperature (exceeding 212°F) drying schedules for both softwoods and hardwoods.

Experienced kiln operators may use the resport as a general guideline, altering the schedules according to individual kiln conditions and wood property variations. Most dry kiln schedules in the report were intended for use with steam-heated kilns with temperature and humidity closely controlled.

This publication groups commercial woods according to their geographical origins: United States and Canada; Latin America (Mexico, Central America, South America); Asia and Oceania; Africa; and Europe. For easy cross-reference, a common name-botanical name list is included as an appendix.

For a copy of FPL–GTR–57, contact:
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Forest Products Laboratory
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Madison, WI 53705–2398
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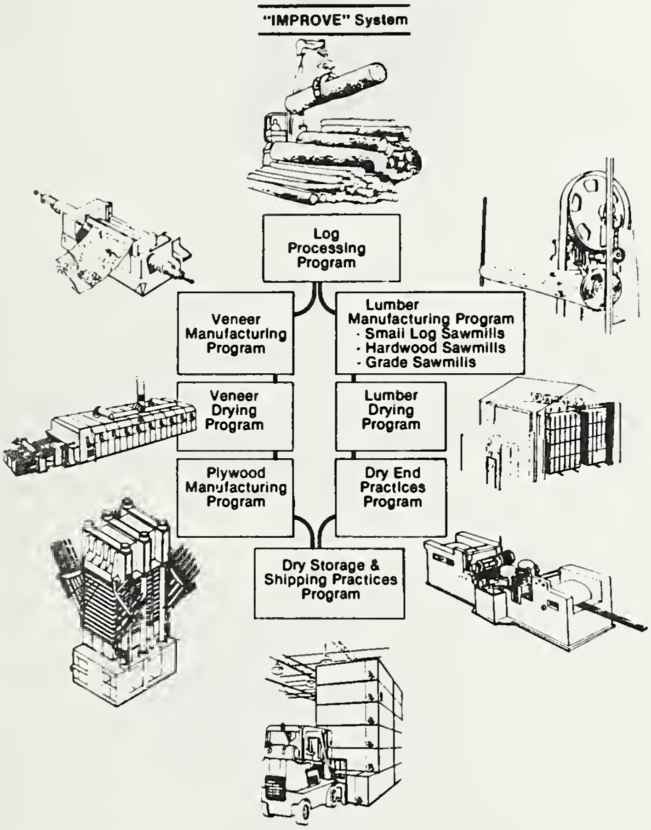
9001

ECHLINE

Processing of Wood Products

IMPROVE

Researchers at the Forest Products Laboratory are developing a system called IMPROVE (Integrated Mill Production and Recovery Options for Value and Efficiency). It is a package of tools to measure and improve processing efficiency and product value and quality in sawmills, veneer mills, and plywood plants. Data collection procedures and computer software combine recovery improvement programs with many of the latest technological and research developments. IMPROVE gives primary processors an easily used system to analyze how well logs are being converted to end products, identify opportunities to increase product yield and value, and predict the effects of proposed improvements.



The IMPROVE system consists of eight major programs, each capable of evaluating specific processes in primary manufacture. The eight areas being covered are log processing at the mill, green lumber manufacture, lumber drying, lumber dry end practices including planing, green veneer manufacture, veneer drying, plywood manufacture, and storage and shipping. Each of these programs basically consists of a test procedure to measure current practices and computer analysis to identify potential areas for improvement and simulate the effects of changing practices.

Each of IMPROVE's major programs can be used independently, but the results of one program can also serve as input for the next. This permits tailoring an analysis to an individual mill's needs. Designed for use on an IBM or IBM-compatible personal computer, each program consists of several routines that analyze various aspects of a given process. As with the programs, the routines can be used independently or in series.

Part of a multiyear research and development program, IMPROVE is a cooperative venture of the Research and State and Private Forestry branches of the USDA Forest Service, the USDA Extension Service, and state foresters. As of December 1989, several routines are available for distribution. These include:

- Statistical quality control routines to analyze size control in lumber and veneer manufacture
- Log analysis routine to tally logs and enter them for use by other routines in the system
- Veneer analysis routines to identify opportunities to improve veneer yield and value
- Several routines to simulate log breakdown in sawmills and aid in mill operation and troubleshooting

Eventually, the researchers expect to produce a total of about 25 wood processing routines.

Information on currently available software and documentation can be obtained by writing:
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For additional technical information, contact:
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ECHLINE

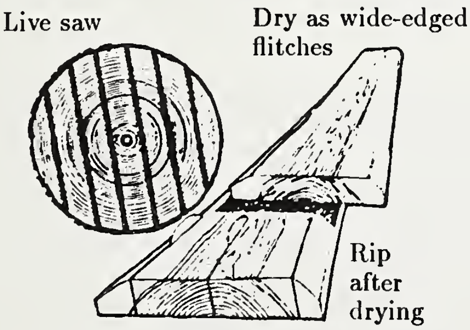
Processing of Wood Products

Saw, Dry and Rip

Until recently, structural lumber produced from hardwoods warped and twisted when it was dried. However, researchers at the Forest Products Laboratory developed the Saw, Dry and Rip (SDR) process which eliminates this problem. As a result, it is now possible to manufacture structural grade lumber from many low- to medium-density hardwoods. The most promising species are yellow-poplar, aspen, eastern cottonwood, sycamore, red alder, blackgum, paper birch, black willow, basswood, soft maple, sweetgum, and black cottonwood.

Potential hardwood species distribution.

SDR begins by live-sawing green logs into 1-3/4-inch unedged planks called flitches. The flitches are dried to an average moisture content of 12 percent, and then ripsawed into studs. This process reduces warp by balancing stresses in flitches, restraining growth stress release, and reducing stress levels by drying.



Drying at a temperature above 212 degrees Fahrenheit also helps the studs remain straight in some species. Stresses in the wood relax at this high temperature and lignin, the bonding agent between fibers, becomes a plastic and allows the wood fibers to slip past each other, minimizing the stress. As the wood dries, the lignin solidifies and holds the wood in an unstressed state.

The SDR process yields volumes comparable to conventional methods for manufacturing structural lumber. In addition, necessary equipment is readily available and existing mills may be easily adapted to the SDR system.

SDR could make hardwood structural lumber a standard commodity and relieve the pressure on the diminishing softwood resources of the West. The Eastern states should benefit in particular because most residential and light-frame building occurs there and they grow a flourishing supply of low- to medium-density hardwoods.

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'ECHLINE
Wood Bonding Systems

Wood Adhesives from Renewable Resources

Adhesives are extremely important to the forest products industry in the United States and in other countries. Over the last 40 years, the use of adhesive-bonded wood products increased dramatically, due largely to the ready availability of low-cost adhesives. Adhesives have increased utilization of the diverse and changing U.S. wood resource and permitted economic production of new, often better, wood products, many of which cannot be made from solid wood.

About 30 to 40 percent of all harvested roundwood ends up in bonded wood panel products, such as plywood and other laminated veneer products, particleboard, waferboard, oriented strandboard, and fiberboard. In 1987, the production of panel products was valued at $5 to $8 billion, not including the value added by secondary or tertiary processing. Most of these materials are used in the building and construction industries. Thus, their manufacture is very important to the U.S. economy and to people's daily lives.

At present, petroleum and natural gas are the primary sources of raw materials for wood adhesives. Prices for these nonrenewable resources have stabilized since the disruptions of the 1970s. But, the strong petrochemicals market of recent years has tightened adhesive raw material supplies and driven prices sharply higher, in some cases as much as 50 to 100 percent higher. Eventually, supplies of petroleum and natural gas will diminish and prices will continue to rise. The forest products industry will need alternative sources of adhesives in order to continue manufacturing durable, bonded-wood products in the future.

Researchers at the Forest Products Laboratory are investigating the use of renewable raw materials (biomass) as sources of wood adhesives. The three basic strategies being pursued are: (1) partial replacement (20 to 50 percent) of petroleum materials used in conventional adhesives, (2) synthesis of totally new polymeric adhesive systems, and (3) production of raw materials currently used in adhesives from renewable resources instead of nonrenewable petrochemical sources. The new adhesives developed through this long-term research will be tested to ensure that they serve the forest products industry as well as the current petrochemical-based adhesives.

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'ECHLINE

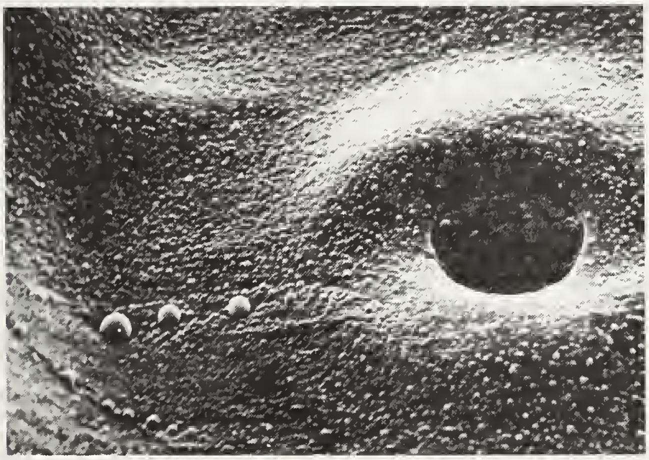
Wood Bonding Systems

Bonding Treated Wood

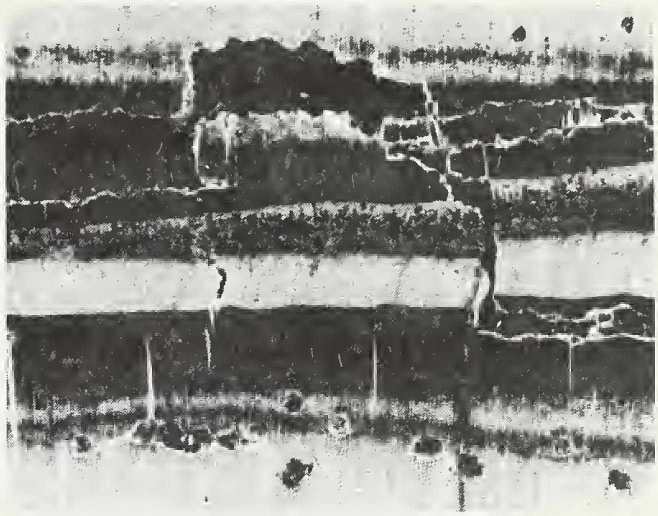
Today's wood products market lacks adhesively bonded lumber and composite products treated with preservatives. The problem arises because present commercial adhesives will not adhere to surfaces treated with waterborne-salt preservatives, such as chromated-copper-arsenate (CCA). Researchers at the Forest Products Laboratory (FPL) are seeking the causes of this incompatibility and ways to overcome it.

The problem is economically significant. Treated wood production fueled this decade's fastest growing segment of the southern pine lumber industry. The market in CCA-treated southern pine now accounts for almost one-half of the total southern pine lumber production. Wood treated with CCA preservatives constitutes about 80 percent of the treated-wood market in the United States.

The difficulties in bonding wood that has already been treated, and the degradation that occurs when a product is treated after bonding, hinder development of preservative-treated bonded lumber and composite products. The potential uses for new products from adhesively bonded lumber, veneer, flakes, and fibers that have been protected from biological deterioration are many and the potential demand is high.



Poor adhesion to CCA-treated wood is partly caused by deposits of insoluble salts blocking contact between an adhesive and the wood's cellulosic cell walls.



An experimental adhesive developed bonds to CCA-treated wood strong enough to resist delamination along the bondline even after severe water-soaking and drying cycles.

FPL researchers are investigating along three approaches to overcoming adhesive-preservative incompatibility. They are identifying physical and chemical causes of interference, identifying new and lesser-used preservatives that may be compatible with commercial adhesives, and improving adhesion to treated wood. Improved adhesion may be achieved by developing new adhesive formulations, investigating existing but untried adhesives, and exploring surface activators and adhesion promoters.

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ECHLINE
Timber Requirements and Economics

Plywood Mill Analysis Program (PLYMAP)

Changing technology, together with cost fluctuations (primarily in wood prices), continually alter the economic equilibrium of plywood mills. To help evaluate the economic effects of changes, economists at the Forest Products Laboratory developed a computer simulation model of plywood processing called PLYMAP (Plywood Mill Analysis Program). This model assesses the net economic effect of changing process parameters in a plywood mill and aids in mill layout and design.

Specifically, PLYMAP analyzes plywood processing by 12 work centers. For each center, the model calculates machine utilization based on user-specified performance-parameter values that define the technology at each center and the size and volume of wood processed. The user can adjust parameter assumptions to achieve a balanced material flow. By specifying representative parameters for each work center, the user can gauge the adequacy of the mill layout and identify bottlenecks for given technology and wood input conditions.

The user also specifies labor, material and energy requirements, and unit costs which the program uses to calculate overall mill production costs. By simulating a range of wood input sizes and technology conditions, the user can determine the conditions that maximize mill efficiency and profitability.

PLYMAP is written in FORTRAN and designed to be run interactively on any IBM or compatible personal computer. The program is command driven, which means it prompts the user to supply answers to a set of questions before proceeding with calculations. The program is suited to most rotary-peeled plywood operations.

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Spelter, Henry. 1990. PLYMAP—A computer simulation model of plywood production. Gen. Tech. Rep. FPL–GTR–65. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory (in process).

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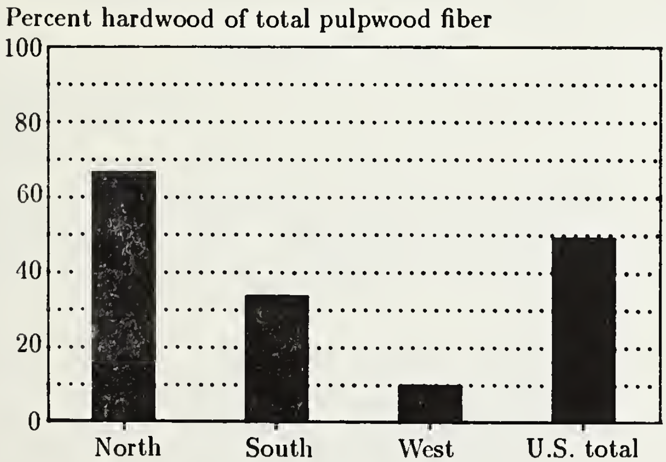
TECHLINE
Timber Requirements and Economics

Computer Model of Fiber Use in the Pulp and Paper Industry

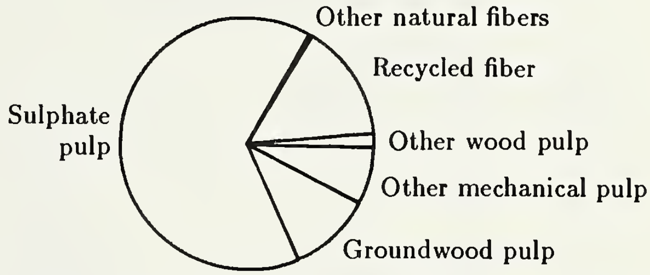
The pulp, paper, and paperboard industry accounts for more than a fourth of all wood products made annually in the United States. Using primarily pulpwood and recycled wood fiber, it produces such diverse products as printing and writing papers, sanitary papers, packaging papers and boxes, and construction paper and board. Manufacturing processes differ greatly by product and by region, especially in types and amounts of fiber required.

The Pulp and Paper Spreadsheet Model, developed at the Forest Products Laboratory, provides a detailed accounting of fiber requirements by product grade, manufacturing process, and region. As such, it is a detailed computer representation of fiber consumption in the U.S. pulp, paper, and paperboard industry.

The model links production and fiber consumption sectors by specific conversion factors. These factors define the amount of wood pulp and recycled fiber needed per ton of product output and the amount of pulpwood needed per ton of wood pulp. The model calculates product output and fiber consumption for ten paper and board grades, eight wood-pulp grades, five recycled-fiber grades, softwood and hardwood pulpwood, and three U.S. regions. Pulpwood consumption is also tracked as either roundwood or residues and by nine subregions.



The Pulp and Paper Spreadsheet Model projects U.S. fiber requirements by product grade, manufacturing process, and region. This chart illustrates projected regional differences in use of hardwood fiber for paper production in the year 2000.



The FPL-developed model tracks the source of fiber used in U.S. paper production from 1990 to 2040. This illustration shows the mix of fiber in the year 2000.

Separate computer spreadsheets represent the industry in 1986 and in each decade from 1990 to 2040. The 1986 spreadsheet compiles all available industry data for that year. The spreadsheets for 1990 and beyond contain projections and assumptions about future production levels, regional distributions, and conversion factors.

The spreadsheet model can be used to calculate U.S. industry's pulpwood and fiber requirements in detail by region for a given level of production. The model could also be used to test alternative assumptions about wood use by product grade and region and to determine the impact of technology changes.

This easy-to-use model was developed using a microcomputer based spreadsheet package. The spreadsheet for each year is available as a separate computer diskette. Any of the model's data or equations can be easily changed, and results are then recalculated automatically. The model can also be enlarged in scope. Factors that could be added include exports and imports, manufacturing costs and fiber prices, wastepaper recovery, and additional manufacturing processes.

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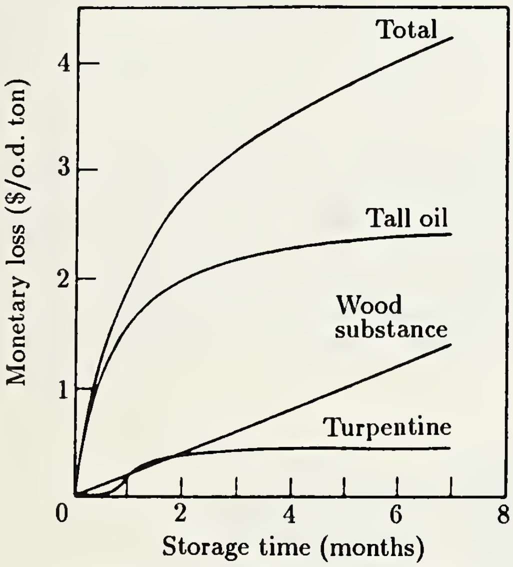
ECHLINE
Pulp, Paper, and Packaging

Storage of Southern Pine Chips

Southern pine chips stored in outside piles lose substantial amounts of wood fiber, tall oil, and turpentine between harvesting and kraft pulping. Ideally, the best means to conserve chipped wood and its byproducts is to eliminate storage or keep the storage time very short. However, in most operations, it is impractical to eliminate all wood storage or operate effectively with short storage times.

Scientists at the Forest Products Laboratory researched chip storage losses and the economic impact of various storage methods. Expected storage losses are shown below.



Correlated monetary losses versus storage times for fresh southern pine chips.

Several storage methods were evaluated. The first-in, first-out (FIFO) procedure has been recommended in the past for reducing deterioration of coniferous species during outside chip storage. Certain mills pulping southern pine chips use it and some think it to be the best method for handling this type of chip.

The last-in, first-out (LIFO) method is by far the easiest to use, as chips are simply added to and removed from the top of a single storage pile. A modified version (LIFO-2) makes use of two storage piles. Many mills approximate one of these procedures. LIFO is not recommended because chips at the base of the pile may deteriorate seriously after long storage.

After study, FPL researchers developed the standby storage method (SSM) as the optimum method for reducing monetary and byproduct losses in southern pine chips. In this method, most of the fresh chips are sent directly to the digesters and a portion of the chips are stored for several months.

Economic comparison of chip storage methods for southern pine

Storage method	Total loss ($/o.d. ton)		
	8-day inventory	16-day inventory	64-day inventory
FIFO	0.82	1.36	2.81
LIFO-2	0.78	1.24	2.55
Standby			
3 months	0.28	0.57	2.25
6 months	0.18	0.37	1.44
6 months/water			
Best estimate[a]	0.20	0.41	1.58
2X best estimate	0.22	0.44	1.73
12 months	0.12	0.25	0.98
12 months/green liquor			
Best estimate[b]	0.14	0.27	1.07
2X best estimate	0.15	0.30	1.17

[a]$0.40/o.d. ton for water treatment.
[b]$0.50/o.d. ton for green liquor treatment.

The above data illustrate that the SSM best reduces monetary losses in the storage of southern pine chips. For any given inventory of stored chips, lengthening the storage time of the chips in the standby pile increases the fraction of fresh chips being pulped and decreases losses of tall oil and turpentine. Treatment of the chips with water or green liquor prior to storage can reduce the rate of chip deterioration and thus permit longer storage times.

Outside chip storage should be considered an integral part of the modern pulping process and must be carefully managed to hold storage losses to a minimum. Even with just a few day's inventory on hand, the SSM method can result in significant savings. For example, a 1,000-ton/day mill with an 8-day supply of stored chips can achieve an annual savings of over $400,000 by switching from FIFO to 6-month SSM. Thus, for many kraft operations, the use of SSM can mean increased byproduct yields and increased mill revenues.

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Reference

Springer, Edward L. 1979. An economic comparison of chip storage methods. Tappi. 62(9):39–42.

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9001

'ECHLINE
Pulp, Paper, and Packaging

Shared Use of the Pulp and Paper Laboratories

Sharing resources for mutual benefit and insight. That's the aim of cooperative research at the Forest Products Laboratory (FPL). For over 75 years, the FPL has supported the U.S. pulp and paper industries through research that improves the way the United States uses its timber resource.

For most of this period, the great strength of the U.S. industry diminished the need for research teamwork between government and industry. This has changed. Increasingly, the United States competes on an international basis and government and industry must work together in developing technology to enhance international competitiveness.

Recent federal legislation provides new authorities for transferring technologies developed in federal laboratories to the private sector. It also allows the FPL to more effectively work with industry, university, and other groups on cooperative research and development of mutual interest and benefit. The legislation grants new latitude to address rights to intellectual property, such as patents, and industry's need to protect confidential business information.

Among the resources made more available to industry, government and university cooperators are the pulp and paper laboratories at the FPL. These facilities offer cooperators some unique advantages such as the opportunity to explore new areas by sharing equipment and staffing costs and access to the expertise of the FPL staff. Cooperative research at the FPL can also open new perspectives on research problems, provide opportunities to implement newly developed technologies, and create familiarity with the FPL's capabilities, which can lead to expanded cooperation.

Proposals for cooperative work using FPL pulping and papermaking facilities are welcome. Each potential project is judged independently of whether the cooperator is an industry, government, or university group. But because the FPL is publicly funded, all projects conducted must relate to the mission and goals of the USDA Forest Service and the FPL.

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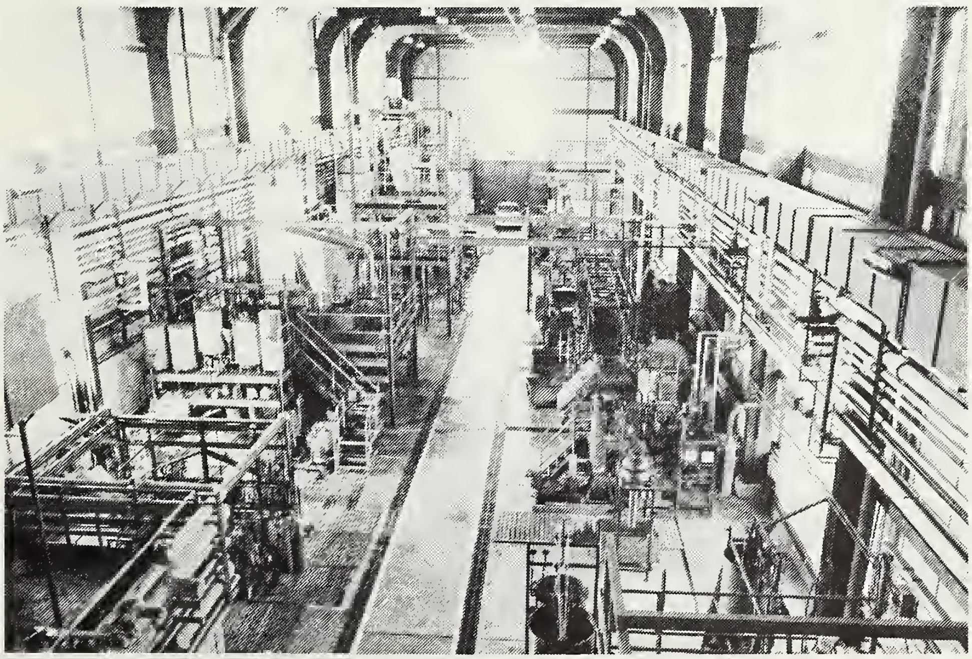

A 45,000-square-foot building contains extensive pulping and papermaking facilities for demonstration and research.

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FPL Spaceboard

Researchers at the Forest Products Laboratory (FPL) have developed a structural product concept called Spaceboard. It consists of two symmetrical halves bonded together to form a three-dimensional board. When joined, the molded side of each half creates numerous geometric-shaped cells in the board's center.

The Spaceboard components are produced by press-drying fiber against compressible rubber molds. Using this technique, Spaceboard can be made thin enough (1/8 in. (3 mm)) for strong, lightweight corrugated containers or thick enough (more than 3 in. (75 mm)) for wall or floor panels.

A significant benefit of using Spaceboard in shipping containers is that Spaceboard can be made uniformly strong in every direction. Laboratory tests show that, using the same amount of wood fiber, Spaceboard is between 30 and 200 percent stronger in both major directions than conventional corrugated fiberboard is in its strongest direction. The press-dry molding technology and the special core configuration impart this strength.

Further refinements have shown the feasibility of producing Spaceboard with the wet strength and dimensional stability necessary to build engineered structures. Spaceboard's unique characteristics as a building material are its high strength per unit weight ratio, its design versatility, and its adaptability to a wide range of fiber feedstocks. A product's skin thickness, cell size and shape, sandwich thickness, and core density can all be tailored for particular product applications. It is also an excellent candidate for production of products using "unclean" recycled fibers.

The full potential for applications of Spaceboard and its economic benefits continues to be explored. Because of its many design and processing attributes, Spaceboard has a broad range of possible commercial applications. Spaceboard has good potential for use in commercial and residential construction as wall, floor, and roof panels and for application in furniture requiring flat or curved panels to be laminated or upholstered. In its thinner configurations, Spaceboard has demonstrated its utility in a wide range of packaging applications. Regardless of the end product, the Spaceboard concept offers a new and more efficient way to use virgin or recycled wood fiber for structural products.

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References

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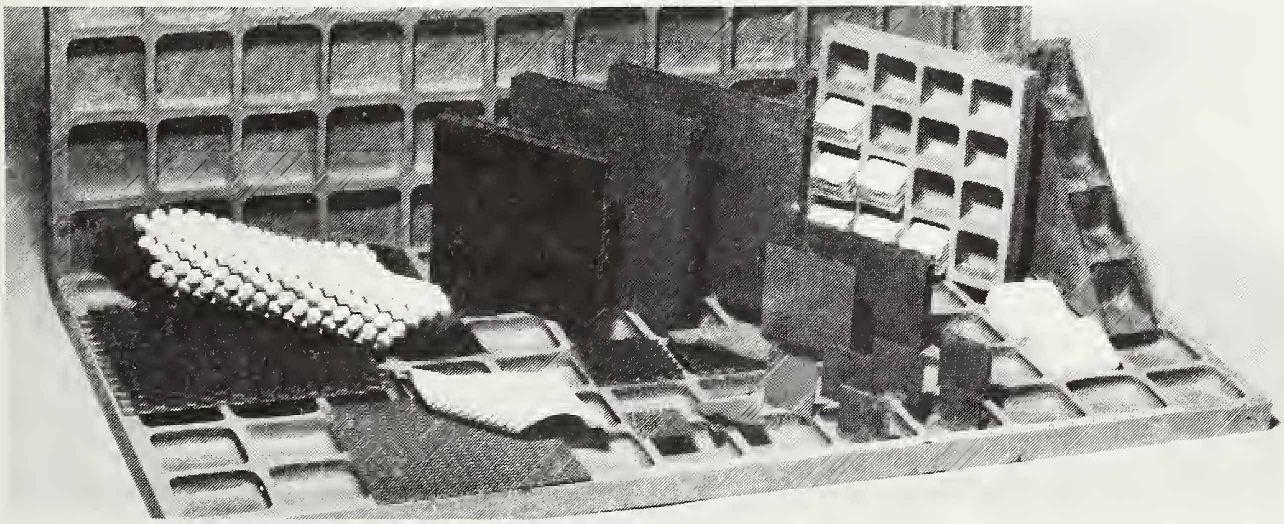


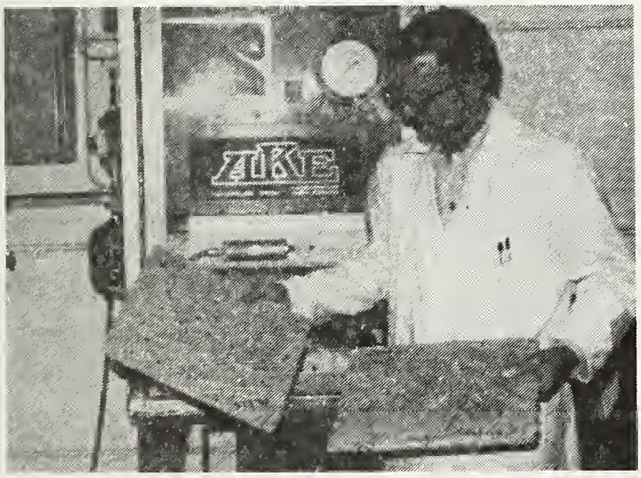
A variety of product configurations are possible using the Spaceboard concept. Spaceboard is formed on the flexible, white, rubber molds shown on the left. M89 0068

'ECHLINE
Fiber and Particle Products

Chemical Modification of Wood

A worldwide team of scientists, led by Roger Rowell of the Forest Products Laboratory (FPL), is currently studying the chemical modification of wood and reconstituted wood products. Studies on improving wood properties through chemistry began at the FPL in the late 1930s. They were expanded in 1972, with the advent of new technology, improved analytical instrumentation, and environmental concerns for toxic methods of wood protection.

Rowell and others established that chemical modification of solid wood by epoxidation or acetylation greatly improved dimensional stability. Stability improves because these procedures bond chemicals to the cell wall polymers, resulting in bulking.

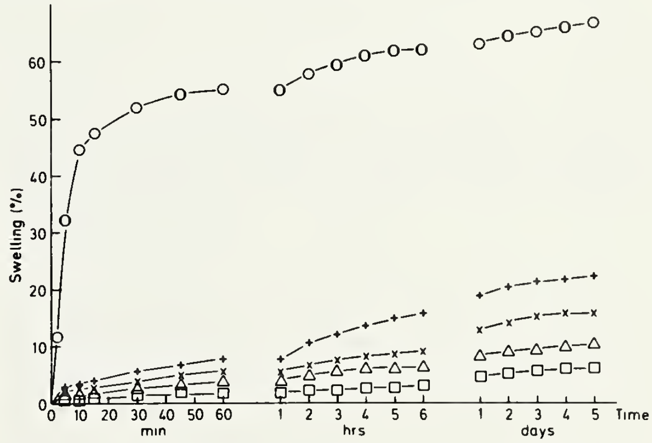


Roger Rowell with acetylated flakeboard samples at Chalmers University, Goteberg, Sweden.

Chemically modified wood swells nearly to its green dimensions so little additional swelling occurs when the modified wood gets wet. Modification of solid wood with anhydrides, epoxides, and isocyanates has reduced swelling as much as 75 percent at bonded chemical weight gains of 20 to 25 percent. The process also produces biological resistance when the bonded chemical is distributed in the polymers that marine organisms, termites, and decay fungi attack.

The FPL modification methods developed for solid wood apply directly to reconstituted wood products because standard operating procedures in the composite panel industry are exactly those required for successful chemical modification. They are dry wood materials, spray chemical addition for maximum distribution, small sample size for good distribution, and high temperature and pressure in product formation.

In tests using southern pine, aspen, and Douglas-fir flakes, acetylation reduced thickness swelling by 85 to 90 percent in flakeboards made from the acetylated flakes. Repeated water soaking/ovendrying tests showed that both epoxidation and acetylation decreased both reversible and irreversible (springback) swelling in flakeboard as compared to untreated boards. (Springback occurs when residual compressive stresses imparted during the pressing process are released.)



Rate of swelling in liquid water of aspen flakeboard made from acetylated flakes. ○ control, + 7.5 weight percent gain (WPG), × 11.5 WPG, △ 14.2 WPG, □ 17.9 WPG. (ML85 5494)

Particleboards made from acetylated chips also show greatly improved resistance to tunneling bacteria and brown-, white-, and soft-rot decay fungi as well as decreased hygroscopicity. The greatest potential for chemical modification appears to be in dimensionally stable, biologically resistant wood composite products, whose commercial application could be very large. This and other ongoing research brings FPL scientists together with scientists in many other countries, including China, Sweden, Finland, Poland, the United Kingdom, Denmark, France, Germany, New Zealand, Australia, and Japan, in studies on acetylation and other chemical modification techniques.

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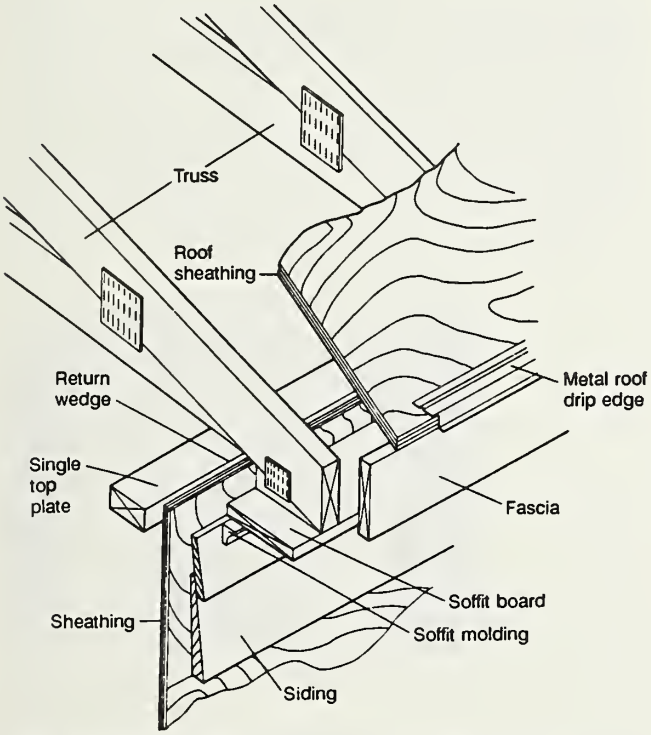
9002

TECHLINE
Engineering Properties and Design Criteria

Wood-Frame House Construction



Sample of detailed diagrams included in *Wood-Frame House Construction*.

The newly revised *Wood-Frame House Construction*, Agriculture Handbook 73, presents sound principles for building homes and guidelines for selecting materials that will provide long service. As a construction guide, the handbook delineates sound building practices for experienced builders, apprentices, and do-it-yourselfers alike. As a textbook, it provides basic information to the student. As a standard, it provides a basis for judging the quality of residential construction. Since its first edition in 1955, this manual has been the authoritative guide to wood-frame house construction.

The manual begins by describing preconstruction considerations and a general schedule for completion. The next three chapters describe laying the groundwork, framing and closing in, and completing the shell. Chapter 5 discusses specialty items such as fireplaces, chimneys, porches, and driveways. The remaining chapters describe interior work, finishing touches, and special topics such as protection from decay and termites, noise control, and wind, snow, and seismic loads. The manual also contains an annotated bibliography and a glossary.

Completely rewritten in 1989, this 266-page manual reflects major new advances in home building during the past decade. Its new features include the chapter on preconstruction and technical notes on concrete, treated wood, lumber and plywood grades, nail selection and use, heat flow, and insulation. Also added were information on new materials and the use of manufactured components, greatly expanded discussion of energy conservation and efficiency, tables of engineering design data for structural elements, and an expanded and annotated list of additional readings.

This new edition draws upon the combined knowledge of industry and government to present the state of the art in wood home construction. The Research Center of the National Association of Home Builders and the USDA Forest Service, Forest Products Laboratory, jointly prepared the manual, with the cooperation of the Canadian Wood Council, National Forest Products Association, National Lumber and Building Materials Association, U.S. Department of Housing and Urban Development, and many individual experts.

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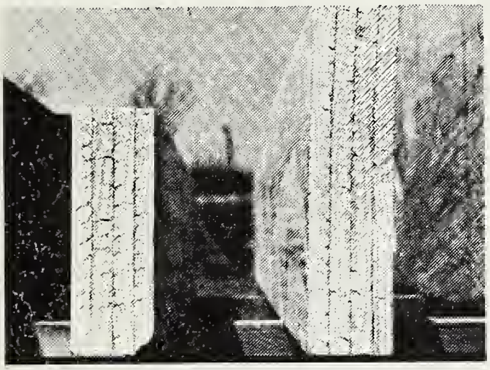
9002

Laminated Veneer Lumber

Parallel-laminated veneer panels, when ripped into lumber widths, are called laminated veneer lumber (LVL). Researched extensively at the Forest Products Laboratory (FPL) in the 1970s, this veneer processing technology combines existing plywood manufacturing methods with new laminating techniques to develop a product with greater uniformity and predictability than solid lumber. The strength of LVL specimens compares favorably with most high-strength lumber grades. As a result, LVL offers a viable alternative to structural lumber.



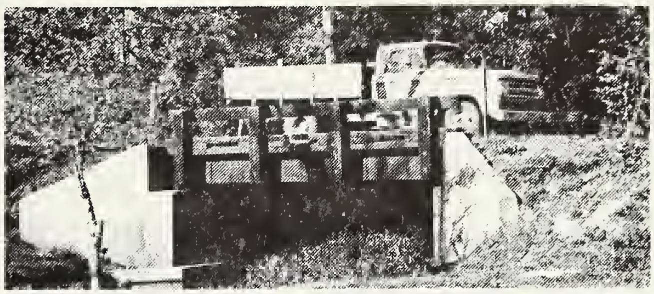
End view shows thick veneer slices are glued together to form LVL.

Most operations that produce LVL for structural use are similar to those for plywood. Veneer is rotary peeled, dried, spread with adhesive, assembled in the desired configuration, pressed (either in conventional presses or on a continuous or step basis), and ripped to width.

The furniture industry has used LVL for many years to produce curved furniture parts. Recently, more LVL has appeared in the marketplace as high-quality, solid-sawn structural lumber becomes more scarce and expensive. The markets for LVL appear limitless—it can be used for truss components, I-beams, bench seats, truck decking, door/window headers, scaffold planking, ladder stock, bridge stringers, and other interior and exterior applications.

Products made from LVL practically eliminate problems of warping and checking because the veneer is dried before gluing. Because laminating disperses wood defects, most mechanical properties will be more uniform than those in comparable-quality, solid-sawn wood. With the efficiency of veneer peeling, a log yields 15 to 30 percent more LVL product than solid-sawn product. In addition, preservative treatment of some species is more effective on LVL materials.

In the past 15 years, an FPL-developed database has contributed significantly to development of standards for



Exterior application—stringers and decking made of LVL were used in the construction of this bridge.

Interior application—LVL material can be used very effectively for door/window headers.

LVL products. The database focuses on raw material options, processing alternatives, product performance levels, system and product economics, and alternative marketing opportunities.

The future for this industry looks promising. The American Institute of Timber Construction provides for LVL as a substitute for tension laminates in glued-laminated beams. An American Society for Testing and Materials task group is working on a general format for evaluating structural lumber substitutes, and the American Plywood Association has proposed a standard that will use performance ratings and provide for trademarking based on the mechanical capabilities of the product.

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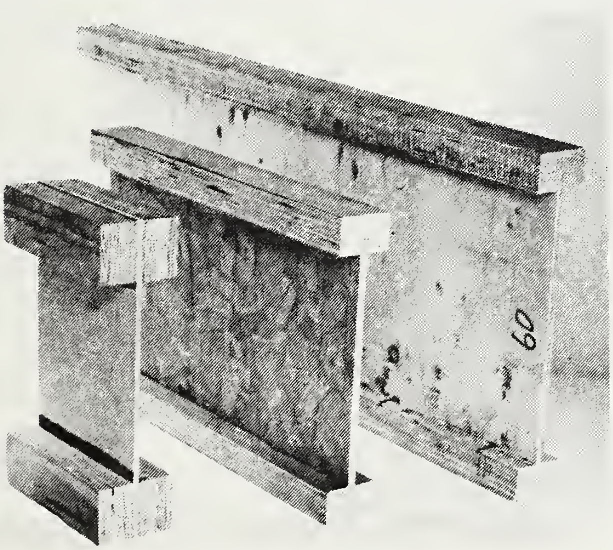
'ECHLINE
Engineering Properties and Design Criteria

Engineered Structural Composites

Although wood has supplied many basic human needs for thousands of years, this essential and renewable resource is not limitless, especially where construction-quality lumber is concerned. Building material manufacturers are already experiencing a shortage of the large, high-quality logs needed for sawn lumber and plywood.

One solution to this supply problem lies with the development of materials known as "reconstituted wood" or "wood composites." In producing such materials, logs are first broken down to thin veneers, flakes, particles, or fibers and then reassembled (usually via gluing) into structural products. The breakdown, reconstitution, and final manufacturing are aimed at producing composites with engineering properties that will meet specific end-use requirements. Thus, high-quality products such as composite I-beams and oriented strand board can be manufactured from a resource that includes low-quality trees.



I-beams from reconstituted products. The two experimental products (on the left) have a hardboard web and a flakeboard web. The sample on the right is a commercially available product with a plywood web.

Composite I-beams are a fast growing sector of the wood products industry, with at least 15 manufacturers producing material that is available nationwide. These products are used extensively in floor and roof systems of both residential and commercial buildings.

Continuing research at the Forest Products Laboratory is aimed at developing improved processes for reconstituted wood and structural products and defining the engineering properties as a function of the resource, manufacturing process, and end-use requirements.

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9002

'ECHLINE
Biodeterioration and Protection

On-Site Protection of Structures

These experimental deck units demonstrate the beneficial effect of in-place preservative treatments.

Research at the Forest Products Laboratory has demonstrated that the service life of exterior wood not in contact with the ground can be extended for many years by surface application of a wood preservative. Brushing or brief immersion of wood in a preservative protected Douglas-fir decking for more than 20 years. This type of treatment, however, is not intended for wood used in ground contact. Wood in contact with the ground should be treated commercially by pressure impregnation of a preservative.

Preservatives can be applied by brushing, spraying, or brief soaking at the construction site or in a routine maintenance program. The job usually dictates the application procedure. Soaking generally provides best insurance of complete coverage of surfaces needing protection. Surface application of preservative is more effective if done before construction because all surfaces and joints can be reached by the preservative.

The increase in service life expected because of such treatment varies, depending on such factors as species, size of timber, climate, and preservative used.

This type of treatment is a preventative, not a remedial, measure. It will not reliably eradicate decay already established in wood. Decay that has progressed far enough to produce external signs of its presence usually is too deep in the wood to be reached by a preservative.

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'ECHLINE
Energy

Forest/Energy News

A new Forest Service energy newsletter about the use of wood for energy and energy conservation in forestry and forest products applications began publication in May 1989. Titled "Forest/Energy News," it succeeds a similar newsletter, QUADS, which was published from 1978 to 1986. The new name was chosen to clearly convey the publication's scope to its readers.

"Forest/Energy News" is distributed electronically, but a small number of hard copies are also produced. Its content focuses on energy within the Forest Service, but also covers developments in both the public and private sectors that can influence use of wood for energy. Comments and contributed articles are welcome and should be sent to the Energy Coordinator at the address listed below.

The newsletter responds to a March 1989 Forest Service action plan for expanding the contribution of wood to national energy goals. The plan calls for more awareness of energy opportunities so that the Forest Service can respond to growing needs for energy from wood and any changes in an increasingly import-dependent U.S. oil supply.

The main purpose of the action plan is to improve the visibility of energy activities of the Forest Service. Besides the newsletter, the action plan includes efforts to organize a Forest Service steering committee, energy coordinators, and a Federal Interagency Energy Committee.

The Forest Service energy program will also produce and circulate case studies of successful energy projects, develop proposals for National Forest System sales policies and obtain outside input on establishing research priorities. Other activities will include expanding the utilization of wood for energy and comparing the air quality effects of burning wood with the effects of fossil fuels or alternatives such as nuclear.

Closer coordination of Forest Service energy efforts will maintain awareness of new developments in wood for energy, establish a focal point for energy information and activities, and facilitate coordination with others, particularly the Department of Energy.

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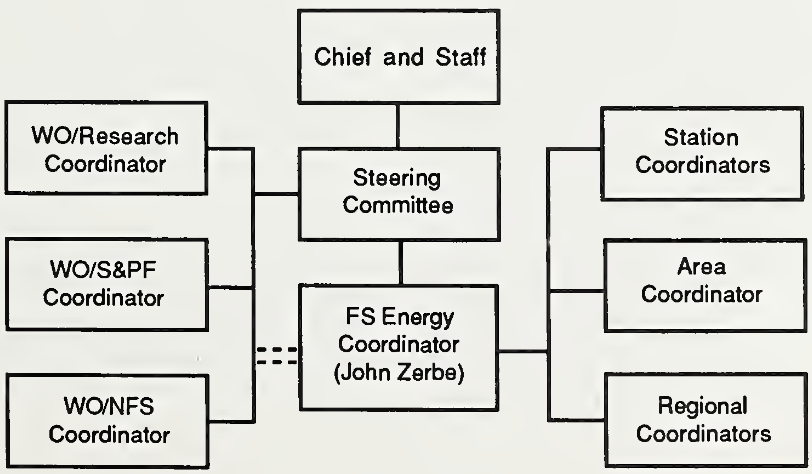

Coordination of Forest Service Energy Program

National Wood Products Extension Program

Ted Peterson has directed the National Wood Products Extension Program since 1985.

Wood's importance as a unique, renewable, energy-efficient raw material continues to increase in the United States and abroad. Effective use of wood and the development of wood-based industries requires continued adoption of new wood products information and technologies. Significant opportunities exist to improve the growing, harvesting, and marketing of timber, the productivity and competitiveness of wood-using industries in rural America, and the use of wood by consumers. But capitalizing on those opportunities requires knowledge of the latest wood products research information.

The National Wood Products Extension Program (NWPEP) facilitates the transfer of wood products technology developed at the Forest Products Laboratory and elsewhere. Its key information network is the nationwide Cooperative Extension System. NWPEP strongly links Extension with important national wood products technology transfer efforts of the Forest Service, other federal and state agencies, and industry.

The Forest Products Laboratory serves as the headquarters for the National Wood Products Extension Program because of its strong history in all aspects of fundamental wood products research and its cooperative relationships with the University of Wisconsin–Madison. FPL has helped extend the world's supply of wood through more efficient raw material use, through increased product longevity, and through creative product development. Wood products research information from FPL and other agencies and universities fuels NWPEP's activities.

The National Wood Products Extension Program publishes the *Extend* newsletter designed to inform Extension personnel about current wood products research information and educational materials. Other activities include the development of national communication networks for disseminating wood information and for targeting technology development and utilization. The program also develops publications and training materials, maintains a computer bulletin board (WOOD), and provides professional consultation in wood use.

The National Wood Products Extension Program is funded by the Extension Service, U.S. Department of Agriculture, through a cooperative agreement with the University of Wisconsin Cooperative Extension Service and with support from the USDA Forest Service, Forest Products Laboratory, at Madison.

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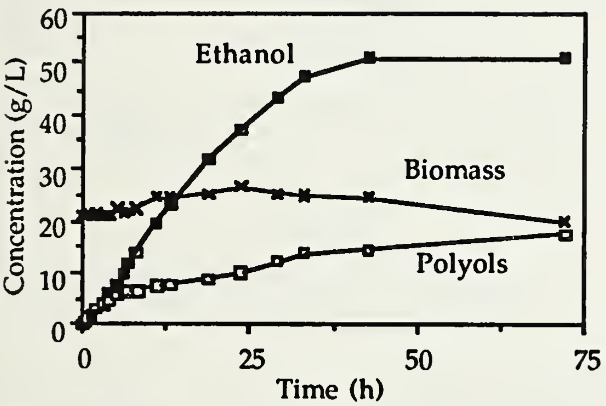
TECHLINE
Microbial and Biochemical Technology

Ethanol Production from Xylose

Using the xylose produced when wood is hydrolyzed has long been a technical barrier to fermenting other sugars produced in the same process. Xylose is an abundant sugar in hardwood hemicellulose, and it is readily recovered through acid or enzymatic treatment. The yield of xylose from the hemicellulose of red oak is almost equal to the yield of glucose. Unlike glucose, however, xylose is not fermented by *Saccharomyces cervisiae* or other common yeasts.

Researchers at the Forest Products Laboratory have found that a few yeasts, most notably *Pachysolen tannophilus*, *Candida shehatae*, and *Pichia stipitis*, can ferment xylose to ethanol at yields of up to 0.44 g ethanol/g xylose and at concentrations of as much as 56 g/liter.



Candida shehatae will convert xylose to ethanol at recoverable concentrations in a fed-batch fermentation.

The addition of glucose to xylose fermentations can increase ethanol yields and concentrations. Maximal ethanol fermentation rates and yields are obtained in fed-batch fermentations.

Both ethanol and xylitol are produced. Ethanol is used in pharmaceuticals and as an octane-enhancer in unleaded fuel. Xylitol is a non-sugar sweetener that does not promote tooth decay and has excellent confectionary properties.

Toxic lignin degradation products can create special problems when fermenting some acid hydrolysates. However, dilute acid hydrolysates from sulfite pulps can be treated to render them fermentable.

FPL researchers have produced improved strains of *P. tannophilus* and *P. stipitis* through mutagenesis and strain selection. Biochemical and physiological studies indicate that the induction of alcohol dehydrogenase is critical to a successful fermentation.

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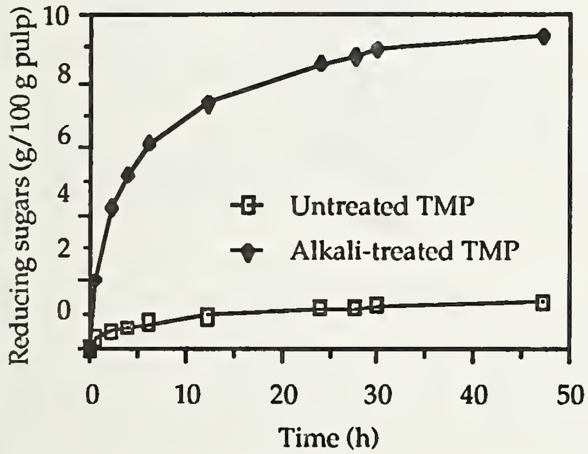
9002

TECHLINE

Microbial and Biochemical Technology

Selective Removal of Xylan from Hardwood Pulps

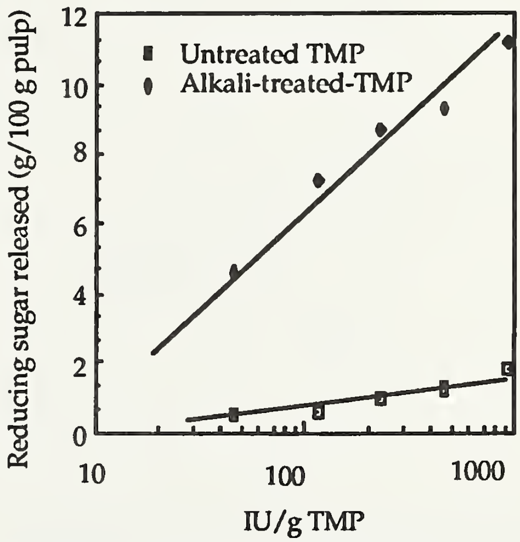
Researchers at the Forest Products Laboratory have found that enzymatic hydrolysis can selectively remove xylan from hardwood thermomechanical and kraft pulps. The resulting fibers are more porous and more readily bleached by oxygen or hydrogen peroxide, and they require less energy to refine. Enzymatic removal of this hardwood hemicellulose can therefore improve some pulp properties while providing feedstocks for useful byproducts.



Thermomechanical pulp resists enzyme treatment, but xylan is readily removed following treatment with dilute alkali.

Wood consists of three principal chemical components, cellulose, hemicellulose, and lignin. Cellulose makes up about 40 to 50 percent by weight, hemicellulose and lignin each compose about 20 to 30 percent, depending on the wood species.

In hardwoods, the principal hemicellulosic sugar is xylose. After xylose is removed by enzymatic hydrolysis, it can be fermented to a number of useful products including ethanol and xylitol. Ethanol is used in pharmaceuticals, and as an octane-enhancer in unleaded fuel. Xylitol is an non-sugar sweetener that does not promote tooth decay and has excellent confectionery properties.



Significant sugar removal can be attained with relatively little enzyme.

The next step in this research will be to develop enzyme treatment processes that will recover xylose in good yields and at high concentrations. These sugar streams will then be fermented to xylitol for food use. The enzyme-treated fiber could also be incorporated in composite materials.

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Reference

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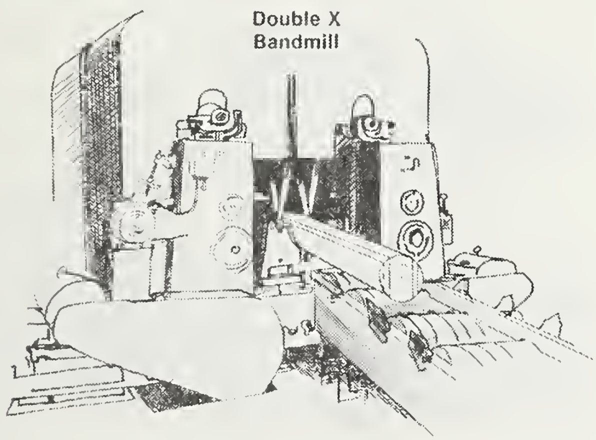
'ECHLINE
Processing of Wood Products

Double-X Bandmill

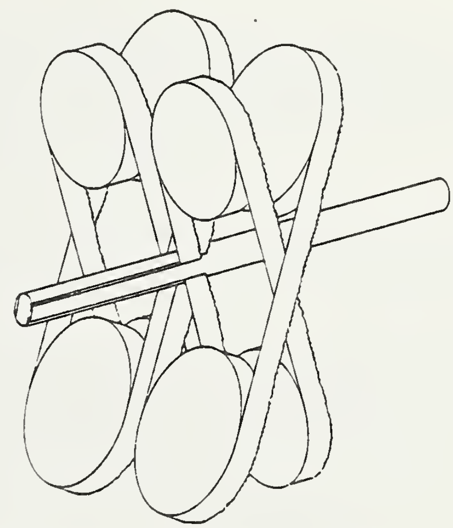
Conventional multiple bandmills consists of two pairs of bandmills mounted one behind the other. Typically, they are separated longitudinally by 1-1/2 feet to as much as 6 or 8 feet.



Artist's conception of Double-X Bandmill.

When logs are sawn by a conventional multiple bandmill, the first pair of bandsaws makes two sawlines near the outside of the log. The second pair of bandmills makes another two sawlines closer to the center of the log. As the first two sawlines are made, growth stresses within the log are relieved. This growth stress relief allows the log to move before it reaches the second pair of bandsaws. The log movement causes variation in the thickness of the boards sawn by the second pair of bandsaws.

The Double-X Bandmill makes all four sawlines at the same time, so log movement from growth stress relief does not result in sawing variation. The sawblades of the two bandmills on each side of the log are crossed so sawteeth are beside each other in the cutting region. This is accomplished by mounting the loop of one sawblade within the loop of the other.



The Double-X Bandmill uses two pairs of crossed bandsaw blades to cut four sawlines simultaneously in a log or cant.

In addition, a third bandmill can be mounted on each side with its sawblade outside the other two, allowing six sawlines at the same time.

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Reference

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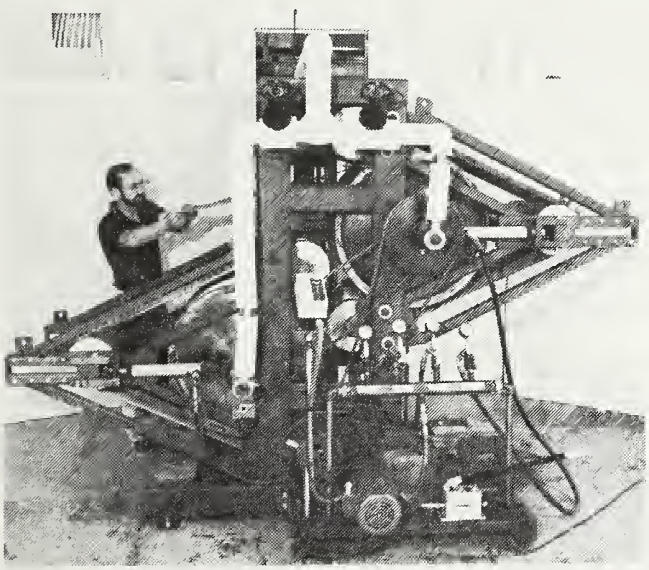
9002

TECHLINE
Processing of Wood Products

Modular Veneer Press Dryer



Modular veneer press dryer.

Almost all face veneer looks good when cut, but much of it becomes wavy, wrinkled, and brittle in the dryer. A severe kind of wrinkling called buckling sometimes occurs, caused by uneven drying and shrinkage of the veneer. The problem is worse with veneer containing tension wood and juvenile wood, which is more prone to longitudinal shrinkage. Yet, these problem woods are appearing more frequently in logs used by veneer producers.

Fortunately, the problem can be eliminated by holding the veneer flat as it dries. This can be done in a press, but face veneer is so thin (1/32 in. or less) that it starts to dry before the press closes. In addition, applying light and uniform pressure is difficult with press plates that may not be perfectly flat themselves.

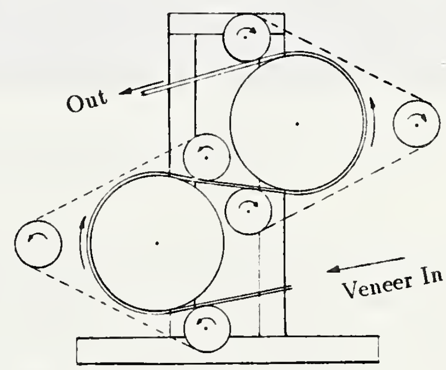
A solution is the modular veneer press (MVP) dryer developed at the Forest Products Laboratory (FPL). The modular veneer press dryer combines the continuous operation of a hot-air dryer with the restraint of a platen press dryer. It dries veneer by direct contact with rotating heated drums arranged in series. Each drum has an endless flexible belt arranged so that the belt wraps halfway around the drum. The veneer is heated on opposite sides by successive drums. The belt holds the veneer tightly against each drum at a typical pressure of 2 lb/in^2.

Veneer dried by the MVP dryer was significantly flatter than that dried by a commercial jet dryer. The MVP-dried veneer also shrank less in width, but more in thickness than the jet-dried veneer. Thickness shrinkage with the MVP was less than with a platen press dryer or roller dryer.

Researchers at FPL arranged a drying test with Freeman Corp. in Winchester, Kentucky, to compare the performance of the MVP dryer with their jet dryer. Because the value of buckled veneer is 15 to 20 percent less than that of flat veneer, buckling costs them an estimated $45,000 to $60,000 per month.

Matching test pieces were dried in the Freeman Corp. dryer and in the MVP dryer at FPL, then compared for shrinkage and flatness. The most significant result was the improvement in flatness for the MVP-dried veneer.

The MVP dryer also showed promise for flattening veneer that had buckled in the jet dryer. The veneer was steamed between wet canvas during one pass through the MVP dryer and redried during a second pass. No evidence of buckling remained after redrying.



Path of veneer in dryer.

Currently, the FPL is seeking an industrial partner to develop a commercial-scale version of the MVP dryer. Implementation of this technology could improve veneer quality and open the door to making quality veneers from difficult species.

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9002

Press Dry Papermaking

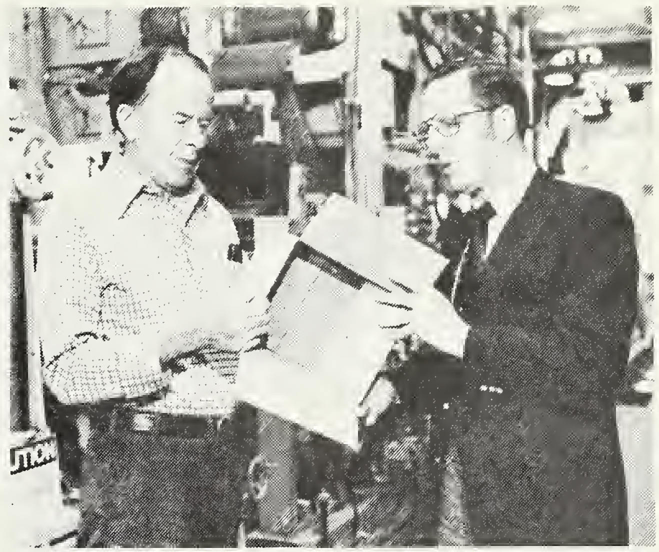
More than half of the wood harvested in the United States ends up in the production of paper or paperboard products. The high-strength paper used in corrugated containers, such as linerboard, has historically been produced from the long, easily bonded fiber of softwood species (primarily southern pines and Douglas-fir). However, the vast resource of hardwoods in the United States could also be the raw material for the production of linerboard and other packaging grades. Hardwood species occupy 55 percent of the forested land in the United States but account for only 25 percent of the country's forest products.

Researchers at the Forest Products Laboratory (FPL) have developed a concept for drying paper called press drying. It overcomes the traditional problems of lowered burst strength and slow wire drainage in the production of linerboard from hardwoods.

In conventional papermaking, heat and pressure are applied separately to a wet fiber web of wood pulp. In press drying, heat and pressure are applied simultaneously to the wet web. This forces fibers into close contact, increasing conformability of the fiber and, thus, fiber-to-fiber bonding. The heat and pressure also promote natural polymer flow of the hemicelluloses and lignin on the fibers surface. Hemicellulose flow promotes increased strength of the press-dried web and lignin flow promotes increased moisture resistance of the dried web.

Press drying has resulted in exceptional gains in bursting strength and, more importantly, exceptional increases in compressive strength of linerboard made from 100 percent hardwood fiber. FPL researchers successfully produced press-dried linerboard on a slow-speed experimental press dryer using various high-yield, high-freeness pulps from different hardwood species. Press drying has also successfully produced recycled multi-ply boxboard and linerboard from recycled corrugated containers. Current press drying research focuses on the potential of making newsprint from high-yield hardwood mechanical pulp.

The largest single use of wood fiber in United States today is for wood pulp, which creates an industrial demand for over 80 million cords of wood per year. Press drying opens this market to hardwoods, offering an avenue for solving hardwood underutilization in the United States. The press drying concept will produce high-strength papers from either softwoods or hardwoods, creating a new generation of fiber products in which the hardwoods and softwoods are more nearly interchangeable.



FPL press drying pioneers Roy Benson (left) and Vance Setterholm examine a corrugated container made from press-dried components.

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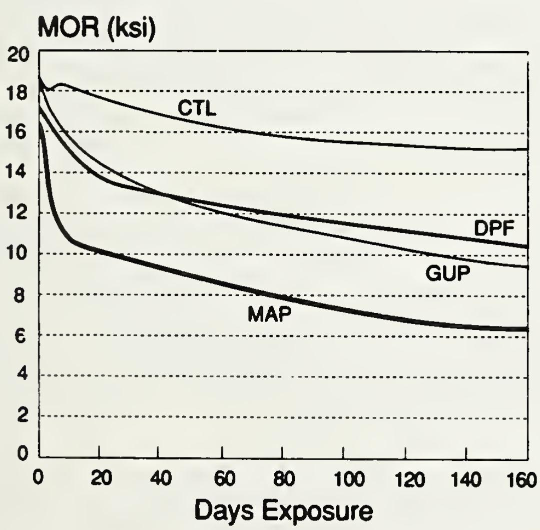
TECHLINE
Engineering Properties and Design Criteria/Fire Safety

Effects of Fire Retardant Treatments on Wood Strength at Elevated Temperatures

Fire-retardant-treated plywood can substitute for noncombustible materials in some structures. However, some commercial fire retardant treatments have weakened plywood used as roof sheathing. The combination of chemicals, moisture, and elevated roof temperatures caused by solar radiation, can prematurely activate some fire retardants, causing the plywood to darken, become brittle, check across the grain, and crumble easily. Because of the regional nature of building codes, deterioration occurred most often in the eastern United States in post-1980 commercial buildings and multi-family dwellings built without parapet walls.

Scientists at the Forest Products Laboratory (FPL) are studying the factors that influence thermal-induced strength degradation. These include fire-retardant formulation, temperature, and wood moisture content.

Different formulations had different effects. Each fire retardant studied accelerated strength loss, but the inorganic salt monoammonium phosphate (MAP) had a significantly greater effect than other exterior or interior organic salts studied. However, even untreated wood suffered permanent thermal degradation when exposed at 180°F. Treated and untreated material showed similar rates of strength degradation once degradation began. Untreated wood is not recommended for use in load-carrying structural applications when environmental temperatures exceed 150°F.



Effects of three fire retardants on bending strength of 0.625- x 1.375- x 12-inch clearwood specimens at steady-state exposure to 180° F (82° C) and 50% relative humidity (CTL=untreated; MAP=monoammonium phosphate, an inorganic salt; GUP=guanylurea phosphate, an interior organic salt; DPF=dicyandiamide phosphoric acid formaldehyde, an exterior organic salt).

After 160 days of constant exposure to temperatures of 180°F, most fire-retardant chemicals caused significant reductions in strength properties in experimental samples. At 130°F, strength reductions for most chemicals were not significant.

Additional research indicated that MAP-treated plywood is lower in bending strength than untreated plywood at all temperatures. As relative humidity increased at 170°F, the rate of strength degradation increased for both treated and untreated wood. However, the effect of relative humidity did not appear to be as influential as that of temperature.

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9009

TECHLINE
Timber Requirements and Economics

Cubic Measurement

Foresters and forest product manufacturers have recognized the need for a universal unit of measurement in wood and wood products since the 1920s. They depend on measurements to quantify how much timber there is, how fast it is growing, how much is to be harvested or left behind, and how efficiently it can be utilized. Yet, most work is carried out using an outdated, inconsistent, and inaccurate unit of measure—the board foot.

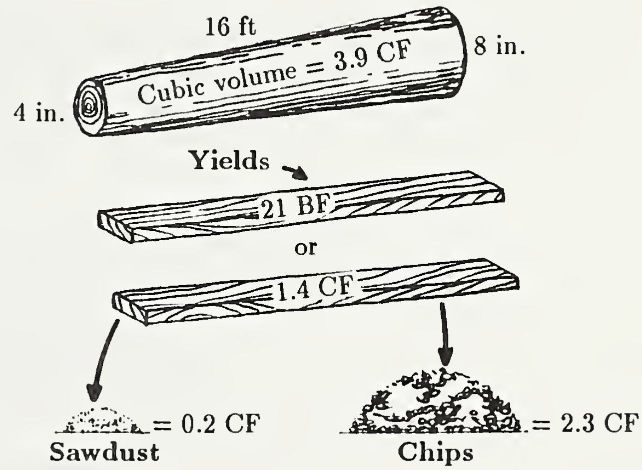
Cubic measurement (e.g., cubic feet as an expression of volume) is an alternative to this old standard. Instead of measuring board feet of logs, cords of firewood, number of poles, and tons of pulp chips, all of these products could be directly measured or converted to cubic measure. As competition within the forest products industry increases, it is critical to have accurate volume and cost information, accountability for all products within the log or tree, the ability to measure the entire array of end products in the same units, an accurate measure of small timber, reliable weight–volume relations, and one consistent measurement system throughout the nation. While the rules and systems currently under development are based on cubic feet rather than cubic meters, the conversion from feet to meters is simple and straightforward. This is a definite advantage in international markets.

Starting in the mid 1970s, researchers in the Timber Quality Research (TQR) Project at the Pacific Northwest Experiment Station published articles explaining the benefits and uses of cubic measurement. They provided mill study results and developed techniques to help a joint Forest Service/Industry task force objectively evaluate alternative scaling methods and individual defect deductions.

The joint task force, a partnership of the forest products industry and the Research and National Forest Systems branches of the Forest Service, developed a standard cubic measurement system that could be applied in forestry, silviculture, cruising and appraisal, scaling, and marketing. This system is being adopted nationwide by the Forest Service, U.S. Department of Interior's Bureau of Land Management and Bureau of Indian Affairs, and State agencies.

The TQR project documented the logic of cubic measurement in a 1984 workshop proceedings, that is still considered a standard reference work.

In 1989, the National Forest Products Association adopted the cubic measurement rules defined by the joint task force as their standard. The growing U.S. acceptance of cubic measurement for wood and wood products



The Scribner scale for this log is 10 board feet, and the volume is 3.9 cubic feet. The log will produce twice the estimated board feet of lumber (21 BF) plus byproducts that cannot be expressed in board feet. The sum of products when measured in cubic feet is equal to the cubic-foot volume of the log.

significantly increases the efficiency and competitiveness of the United States forest products industry nationally and internationally.

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References

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Pruning Douglas-fir

During the past 40 years, pruning has frequently been suggested as a tool for managing of coast Douglas-fir. Numerous studies document the effects of pruning in young stands of Douglas-fir and the literature supports a common theme—pruning is the only way to ensure the growth of significant volumes of clear wood in intensively managed stands. Given current, short harvest cycles and limb-retention characteristics of Douglas-fir, the growth of clear wood in unpruned young stands is minimal.

Researchers at the Pacific Northwest Forest Experiment Station conducted a product recovery study on a stand of 100-year-old trees that were pruned to a height of 17 feet when the stand was 38 years old. Pruning had a substantial impact on veneer grade recovery and a less dramatic impact on lumber grade recovery. For example, a pruned 24-inch log recovered five times the percentage of B-patch and Better veneer compared with the same-size, unpruned log. The recovery of Finish grade lumber averaged more than 30 percent for a pruned 20-inch log; the same-size, unpruned log average about 20 percent.

These study results were used to evaluate the financial return from pruning. Analyses determined the increase in present value per tree, based on rotation length, age at time of pruning, fertilization, and several pricing assumptions.

Researchers developed a computer program (PRUNE-SIM) that allows the user to simulate a financial analysis of pruning coast Douglas-fir. The program calculates the difference in value of trees and stands grown under a variety of management regimes, either with or without pruning.

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References

Cahill, J.M.; Snellgrove, T.A.; Fahey, T.D. Lumber and veneer recovery from pruned Douglas-fir. Forest Products Journal. 38(9):27–32.

Fight, R.D.; Cahill, J.M.; Snellgrove, T.A.; Fahey, T.D. PRUNE-SIM Users Guide. Gen. Tech. Rep. PNW–GTR–209. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 21 p.

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'ECHLINE

Engineering Properties and Design Criteria

Timber Bridge Program

This stressed-deck bridge was installed as a demonstration of new timber bridge technology.

In 1989, the USDA Forest Service began a program to respond to the renewed interest in using timber as a construction material for bridges. Timber bridges offer an economical, durable, safe, and attractive alternative to traditional materials used for bridge construction. Timber bridges are of growing interest because they are economically competitive with other materials and designs, perform well, and are easy to construct and install.

The Forest Service initiative established a Timber Bridge Information Resource Center for technical assistance, funded cost-share demonstration bridges, and expanded timber bridge research. The Center's program is to inform state, county, and local officials, federal agencies, engineers, and contractors about the advantages of using properly treated timber for new and replacement bridges on local and secondary road systems and public properties. The Center also administers the selection and installation of the demonstration bridges.

Through cost-share funding, at least 80 bridges will be constructed nationwide to demonstrate modern timber design concepts. The demonstration bridges emphasize the utilization of native species to stimulate local employment and rural economics.

Performance data from some of these demonstration bridges will be used to obtain approval of new designs from the American Association of State Highway Transportation Officials (AASHTO). Existing AASHTO standards will also be refined to reflect current timber bridge technologies, such as crash-tested guardrail designs and timber from species not formerly used.

AASHTO design standards are recognized nationally and keep transportation systems uniform. They are usually a basis for funding approval by the Federal Highway Administration and state transportation agencies. AASHTO approval of new timber bridge technologies is necessary if timber is to be a viable alternative in many locations, because local projects often receive partial funding from federal or state agencies.

Research is continuing to refine some of the newest designs and develop recommended design criteria. Studies are also being conducted to optimize species availability, treatability, and performance. Researchers are developing and crash testing guardrail designs to provide standard systems that comply with recommended AASHTO guidelines for crashworthy railings. Economic studies are being conducted to better compare the costs of alternative materials and to calculate life cycle costs, including initial costs, maintenance, and longevity.

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TECHLINE
Timber Requirements and Economics

Cost Estimation for Cable Logging Eastern Hardwoods

Over the past 10 to 12 years, detailed harvesting cost data have been gathered for all aspects of cable logging hardwoods. Although detailed and of excellent quality, the data were fragmented and needed compiling in an easy-to-use computerized package.

Researchers at the Northeastern Forest Experiment Station have developed a stump-to-mill cost estimating model for cable logging eastern hardwoods, called ECOST. ECOST estimates the stump-to-mill cost of cable logging eastern hardwoods, using any of several cable yarder systems. It can project detailed cost estimates for felling, bucking, limbing, yarding, loading, and hauling. The hauling estimates include several different road and truck types. The cost can be estimated for a wide range of timber and terrain conditions.

The Eastern and Southern Regions of the USDA Forest Service use portions of ECOST to supplement their timber appraisal methods. Forest Service researchers, academic institutions and forestry consultants have also implemented it. ECOST can also benefit many forest managers and forest products producers. ECOST's success has prompted research on a similar package for ground-based harvesting systems.

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LeDoux, Chris B. 1985. Stump-to-mill timber production cost equations for cable logging eastern hardwoods. Res. Pap. NE-566. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 6 p.

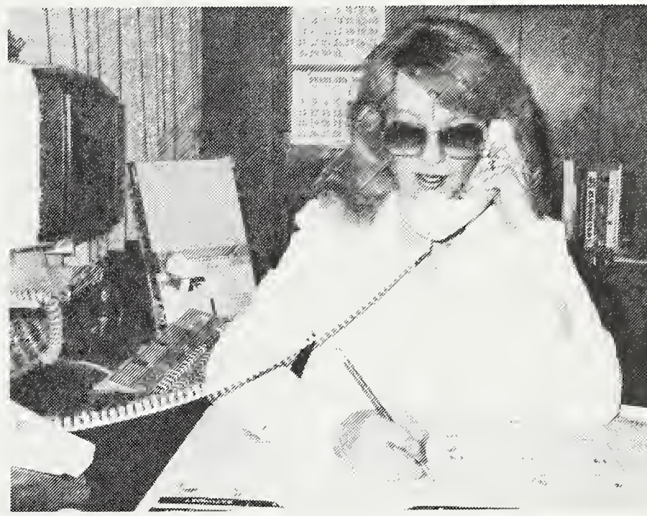
'ECHLINE
Processing of Wood Products

Technical Resource Center on Hardwood Processing

A furniture manufacturer needs to locate suppliers of computer-numerically controlled (CNC) woodworking machinery; a forest products technologist needs current research results to assist in technology transfer efforts; a wood products manufacturer needs to locate information contained in a specific research publication. To meet these and similar needs, the USDA Forest Service established the Advanced Hardwood Processing and Technical Resource Center at Princeton, West Virginia. Its staff can access many commercial databases on completed and current research in wood processing and have developed their own specialized databases on various types of machinery, manufacturers, and dealers. The Center is part of the Forest Service's Northeastern Forest Experiment Station.

The Center supplies information needed to effectively use the substantial U.S. hardwood resource. These trees, which can vary greatly in quality, represent significant potential value. Manufacturing these variable-quality hardwoods into furniture, millwork, and other products creates substantial value-added economic opportunities. Using cost-efficient equipment and applying new technology to the processing of these hardwoods can enhance the competitive position of the United States wood processing industry.

Designed to serve the public as a source of information on the processing of hardwoods, the Center works like this. An individual with a question or concern contacts the Center via phone, mail, or FAX. The Center staff searches the databases and literature and provides the caller with the requested information. The caller may also be referred to a specialist in a particular field for answers to specific questions. There is no charge for this service.



The Advanced Hardwood Processing and Technical Resource Center locates answers for questions about hardwood processing using commercial databases on completed and current research.

The Center is staffed from 8:00 a.m. to 4:30 p.m. (Eastern time), Monday through Friday. Callers may leave a message with the telephone answering service at other times.

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ECHLINE
Processing of Wood Products

Analysis of Computer-Controlled Woodworking Machinery at the Hardwood Processing Center

Researchers at the Advanced Hardwood Processing and Technical Resource Center evaluate machine performance to help wood equipment manufacturers and distributors, consultants, and plant managers determine the types of machines suitable for specific wood processing needs.

Although computer-controlled machines are routinely used in the metalworking industry, they are still relatively new in the U.S. woodworking industry. A variety of reasons for this exist, including a lack of information about where and how these machines can be efficiently used to increase production. The USDA Forest Service established the Advanced Hardwood Processing and Technical Resource Center at Princeton, West Virginia, to conduct analyses of computer-controlled woodworking machines, either individually or as systems composed of several machines.

Researchers at the Center evaluate and analyze machines for a variety of characteristics such as efficiency, yield, safety, computer control functions, and economic criteria. As part of the analysis, standardized criteria for assessing machine performance are developed. The results help equipment manufacturers and distributors, consultants, and plant managers determine the types of machines that are suitable for specific wood processing needs.

The first machine analyzed was a computer-numerically controlled (CNC) router, a machine requiring complex computer-control functions. Specific evaluation criteria were developed and tested on this machine. The criteria included power requirements, spindle motor adequacy for machining various raw materials, accuracy and repeatability of machining, setup time, and processing time. In addition, noise and dust levels were measured. Also, the router's controller was evaluated in terms of ease of use, skills required to operate, and ease of programming. Most of these criteria will apply to other types of machinery as well, such as moulders, tenoners, and multiboring machines.

The Center solicits the cooperation and participation of both the machinery and wood products manufacturers in this machinery analysis and evaluation program. The success of the program will depend, in large measure, on such cooperation. For example, results must be in a form that are useful to industry for making decisions about the use of CNC machinery. The Center will also require cooperation in obtaining machinery on a temporary basis for analysis and evaluation. Provisions of the 1986 Technology Transfer Act can facilitate such close cooperation and proprietary research between industry and government.

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TECHLINE
General

Integrated Harvesting Model

The forests of the Northeast form a 77-million-acre resource of diverse tree and wildlife species. They meet ecological needs, supply useful products, and provide a variety of other benefits such as recreation. This diversity challenges resource managers to examine alternative management systems and select the ones that best provide the desired benefits.

To help managers explore options, researchers at the Northeastern Forest Experiment Station developed a shell structure (computer code and related logic) for a model called MANAGE. The results of the model can help managers effectively integrate silviculture, logging technology, and economics in their decision making. Users can specify silvicultural objectives, logging technology, and economic concerns for specific stands and other resource uses.

MANAGE provides detailed growth and yield estimates, cost and benefit estimates, log quality, and volumes by thinning entry or final harvest. It also produces a financial summary, expressed as discounted present net worth.

To date, MANAGE has been applied primarily for research, but its modeling techniques interest many other users. It is one of the few models that provides good logging and economic results. Integrated decisions, which MANAGE makes possible, benefit all forest users.

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LeDoux, Chris B. 1986. MANAGE: A computer program to estimate costs and benefits associated with eastern hardwood management. Gen. Tech. Rep. NE-GTR-112. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 7 p.

LeDoux, Chris B. 1988. Impact of timber production and transport costs on stand management. Res. Pap. NE-612. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 5 p.

Dual-Constraint Transport Systems

All transport systems are constrained by the maximum weight or volume that can be hauled. Some transport systems are also constrained by the maximum number of pieces that can be hauled. The latter are called dual-constraint transport systems.

The performance of dual-constraint transport systems is very sensitive to the effect of piece size. While they are able to haul multiple pieces, they are not able to do so efficiently and are consistently underloaded. The smaller the piece size, the more pronounced the underloaded condition. Examples of dual-constraint transport systems in the logging industry are rubber-tired cable skidders, cable yarders, multipiece loading machines, accumulating feller-bunchers, and crawler tractor skidders. Examples of transport systems that are not dual-constraint transport systems are log trucks and forwarders.

The load curve intercept method is a new methodology to predict performance of dual-constraint transport systems. With this method, the user observes the operation of the system and records the maximum volume per turn, the average volume per piece, and the average volume per turn. This data permits calculation of the load curve intercept using procedures documented in the reference listed below.

The average volume per turn in a new harvest unit can now be predicted from the maximum volume per turn (from the old unit), the average volume per piece (for the new unit), and the load curve intercept. Combining the average volume per turn with cycle time gives the expected production.

This methodology can predict and explain logging performance in a variety of situations. For example, a cable yarder moved from the West Coast to the East Coast produces much less in its new location. The load curve intercept method could explain why. Or, a logger, used to working in sawtimber stands, is moving into a poletimber stand and wants to estimate production. The load curve intercept method could do it. In another instance, a researcher comparing the performance of two machines in similar stands suspects that the operator of one of the machines was loading it more efficiently, biasing the comparison. The load curve intercept method could verify it.

The load curve intercept method has been applied to rubber-tired cable skidders and cable yarders. Use of this method and application to more systems would give managers a better understanding of logging performance and suggest logging method improvements that require very little cost.

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Peters, P.A. 1988. The load curve intercept method: Estimating the effect of average piece size on skidding costs. ASAE Paper No. 88-7546. St. Joseph, MI: ASAE.

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9001

TECHLINE

General

Skidder-Mounted Herbicide Application Systems

In the past three decades, herbicides have emerged as an important vegetation management tool. Nearly 1.5 million acres of commercial forest land are treated each year with herbicides. Concerns over the environmental impacts of such treatments, particularly when applied aerially, have generated a need for more controllable means of herbicide application. The Chequamegon National Forest and the North Central Forest Experiment Station have cooperatively developed two controlled herbicide application systems that are skidder-mounted and cost effective.

Both systems are skid-mounted for easy mounting and removal and are completely self-contained. The first system, a liquid applicator, utilizes a 380-gallon stainless steel tank, pump, gas engine, necessary piping and valves, a flow metering device, and a Radiarc spray nozzle by Waldrum Specialties, Inc., for dispensing the chemical mix. The heart of the system is a Model SCS-700 chemical injection spray controller by Raven Industries, Inc. The second system is a granular applicator, a Herd Seeder Company Inc. Model 1200C broadcaster with a modified feeding mechanism, a diesel engine, and the Raven controller.

In both systems, the controller is programmed with the system variables and the desired application rate of the herbicide. In operation, the controller maintains the application rate of the herbicide based on the ground speed of the skidder.

The Chequamegon National Forest has applied both systems and reduced their per-acre treatment costs by 60 percent from previously used methods. Cost savings have been so significant that four other National Forests in the Eastern Region are now contracting with the Chequamegon for their herbicide application work.

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A chemical injection spray controller gives this forwarder-mounted application system better control over liquid herbicide application rate. A similar system for granular application has also been developed.

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8912

Chunkwood: An Alternative Material for Building Low-Use Roads

Unsurfaced, single-lane, low-use roads constitute about 75 percent of the 340,000 miles of roads maintained by the USDA Forest Service. Despite their importance for forest management, low-use roads in many countries have deteriorated due to a lack of adequate roadbuilding materials, maintenance, and rehabilitation. Many heavily forested areas of the world remain inaccessible because of severe shortages of conventional roadbuilding materials and fragile ground conditions. A recent international conference on low-use roads identified the need to characterize marginal, substandard, or unconventional materials and document their use for low-volume roads as one of four high-priority concerns.

North Central Forest Experiment Station researchers recently introduced a very unconventional roadbuilding material called chunkwood. A machine known as a wood chunker produces the fist-sized particles of wood at the roadbuilding site from nearby unmerchantable trees. Trees can also be taken directly from the road right-of-way.

Chunkwood has been successfully demonstrated as an alternative material for building low-use forest roads. The North Central Forest Experiment Station, the Chequamegon National Forest, and Michigan Technological University cooperated to construct and evaluate a variety of chunkwood roads, using chunkwood alone or in varied combinations with synthetic fabric and/or gravel. Road sites included a swamp with deep, underlying peat, a fine-grained soil with a high water table, a uniformly graded sand with very deep water table, and an existing road with a series of mudholes. All chunkwood roads performed to an acceptable, but varying, level under heavy truck traffic.

Chunkwood roads are cost-competitive with conventionally built roads. Widespread use of chunkwood for low-use roads will conserve finite supplies of gravel for building high-use roads and eliminate the need to transport roadbuilding materials over long distances. Chunkwood can provide a market for otherwise unmerchantable trees and substantially reduce roadbuilding costs. The use of chunkwood also eliminates the need for unsightly borrow pits which require restoration.

Chunkwood's light weight (one-fifth that of gravel) and other unique properties make it an especially good choice for building roads over swamps. An environmental plus is that the road can be maintained over its useful life and then allowed to decompose and return to nature. An obvious benefactor of chunkwood roadbuilding technology is the military of those countries that maintain a domestic low-use road network as well as roads built in an active theater of operations.

Because chunkwood roadbuilding is in its infant research and application stages, much needs to be learned about its engineering characteristics and design criteria. Despite the lack of established roadway design procedures and standards under varied conditions, it is already clear that chunkwood is a viable alternative material for building low-use roads in forested areas.

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Chunkwood makes a successful roadbuilding material, either alone or, as shown here, in combination with a geotextile fabric.

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8912

TECHLINE
Engineering Properties and Design Criteria

Wood Properties of Managed Hardwoods

Variation in wood properties can create problems during wood processing and so has been the subject of much research. However, variation can also contribute to the distinctive nature of wood and, consequently, make it a very desirable commodity. Variation is influenced by age, environment, and genetic factors.

Researchers at the North Central Forest Experiment Station are studying the influence of age and environment on wood properties. Most previous research examined the influence of management on softwood strength and processing properties and evaluated the influence of silviculture on hardwood density, a good indicator of wood behavior during processing.

Current studies examine properties important to users of high-value, high-grade logs, such as color, texture, and processing properties. Researchers are studying these properties and log value or lumber grade to determine the influence of various silvicultural and management practices. For comparison with previous work, wood density is also being examined.

Results to date have yielded useful information on the growth and processing characteristics of hardwoods. For example, management practices, such as pruning, are absolutely necessary to produce a clear bole of wood when trees are grown under managed conditions and at wide spacings. Evaluations in wood density indicate that black walnut and white oak have similar density patterns from the center of the tree to the bark. This baseline describes the natural variation to be expected within hardwoods. Studies have also shown very little defect associated with drying faster-grown, smaller-diameter black walnut in conventional kilns.

Current research focuses on wood color and wood texture, two very important properties to veneer producers. This study of the influence of soil and site on the color and texture of high-value hardwoods is being coordinated with the fine hardwoods industry.

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References

Phelps, J.E.; Chen, P.Y.S. 1989. Lumber and wood properties of plantation-grown and naturally grown black walnut. Forest Products Journal. 39(2):58–60.

Phelps, J.E.; Chen, P.Y.S. 1989. Wood and processing properties of planted white oak from a thinned and unthinned site. Paper presented at the 43rd annual meeting of the Forest Products Research Society; 1989 June 25–28; Reno, NV.

TECHLINE
Biodeterioration and Protection

Borate Technology Transfer

Borate-based preservatives are a potentially significant addition to the arsenal of treatments that extend the service life of wood used outdoors and above ground. Because of their low toxicity to humans, borates can also be used with structural timbers and indoors and do not require pressure treatment. They are one of the many wood treatment techniques available to help extend the increasingly valuable U.S. timber supply.

These test structures in Mississippi are part of an evaluation of borate-treated building components.

Mississippi State University, Oregon State University, and the USDA Forest Service, through its Southern Forest Experiment Station and Southern Region, are cooperating to distribute information about borates. A technology transfer plan called "Borates for Wood Protection" documents their plans for disseminating this knowledge through 1993. A limited number of copies are available from USDA Forest Service, Forest Pest Management, 2500 Shreveport Highway, Pineville, LA 71360.

Much of the knowledge about borates gained through research is ready for application and is already being demonstrated in test houses at two Mississippi locations. Additional test houses are planned for the Virgin Islands and Puerto Rico. Further demonstrations are being considered for other parts of the United States through the National Parks & Recreation Association.

Videotapes on basic borate technology are available from USDA Forest Service, Forest Pest Management, P.O. Box 2680, Asheville, NC 28802. They are currently producing videotapes on treatment of fence posts, treatment of southern yellow pine, and the construction of the test houses. A brochure will accompany the yellow pine and test house tape. A national conference on treatment of wood with diffusible preservatives is planned for November 28–30, 1990, in Nashville, Tennessee. About 250 participants are expected. The goal of the conference is to present the benefits and limitations of this technology to the wood-using industry.

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United States Department of Agriculture — Forest Service — **Southern Forest Experiment Station** — **Southern Region**

9002

TECHLINE
Fiber and Particle Products

Composite Structural Lumber

Composite joists, plates, and 2 by 6 studs were used in the 1982 NAHB Research Foundation demonstration house.

Traditional lumber and plywood production methods waste timber, using only about half the volume of the logs brought to the mill and less than a third of the actual volume of the harvested trees. The industry also faces problems of increased costs and smaller diameter, knottier trees to process. The declining quality of raw material results in decreased allowable stress values for the lumber and plywood produced from smaller trees.

Lumber made from composite materials addresses these concerns. Composites combine two or more materials with different properties to produce a product with properties superior to those of the components. Scientists at the Southeastern Forest Experiment Station used this approach when they began work on composite structural materials in 1974.

The initial goal of the research was to produce a composite stud for residential construction that would utilize 100 percent of the volume of a timber stand. Researchers envisioned a product that combined high-quality veneer peeled from the better-quality trees with particleboard made from the knotty, upper logs and lower-value, small, crooked trees that would normally be left in the woods. Both hardwood and softwood species would be used in the composite stud, increasing stand utilization.

Many southeastern timber species were considered as potential veneer components. Species were evaluated on their availability, veneer grade/yield characteristics, glu-ability, modulus of elasticity, modulus of rupture, and fastener compatibility (primarily nail withdrawal and lateral load). Studies found southern pine, yellow-poplar, sweetgum, blackgum, and white oak veneers to be suitable for use in composite studs.

Research on the species-dependent characteristics of the particleboard core was not extensive. Both yellow-poplar and sweetgum provided a suitable furnish for the particleboard component. The critical characteristic for any species was having less than 12 percent thickness swell after a 24-hour, cold-water soak.

Builders and industry responded favorably to composite studs produced in a pilot plant run in 1974. This led to further research developing and testing composite joists and composites intended for light-frame trusses. The study also determined the treatability, long-term durability, and fire resistance of the composites. Generally, composite structural lumber compared very favorably with traditional sawn lumber for all construction uses.

Among the many combinations of veneers and flakeboard cores tested, a fully oriented flakeboard core material with excellent mechanical properties was the outstanding development. Composite joists formed with this core material nearly equalled the modulus of elasticity of commonly used structural grades of sawn lumber.

Composite structural lumber has many advantages. It has extremely uniform strength and stiffness properties, is almost warp free, and stays warp free after weathering or treating with waterborne preservatives. The desired length and width of composite lumber can be economically produced regardless of the size of the trees available. Since many species can be used almost interchangeably, essential complete utilization of timber stands is feasible.

Interest in composite structural products continues. A commercial plant was built in Roxboro, North Carolina, in 1986 to produce composite joists and truss lumber. Although research terminated in 1986, the results are available in over 30 technical publications.

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Reference

McAlister, Robert H. 1989. The research and development of COMP-PLY. Gen. Tech. Rep. SE-GTR-53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 23 p.

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9001